Investigation of Horizontal Well Performance Using Hele-Shaw Model

by

Irfan Sami Khan

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

PETROLEUM ENGINEERING

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COLLEGE OF GRADUATE STUDIES

This thesis, written by **Mr. Irfan Sami Khan** under the direction of his Thesis Advisor and approved by his Thesis Committee, has been presented to and accepted by the Dean of the College of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **PETROLEUM ENGINEERING.**

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كلية الدراسات العليا
COLLEGE OF GRADUATE STUDIES

Dedication

I dedicate this thesis to my loving mother

May Allah Almighty bless her

Acknowledgement

In the name of Allah, Most Gracious, Most Merciful

I would like to express my deepest gratitude to my thesis advisor, Dr. Mohamed A. Aggour for his constant support and constructive guidance throughout the course of this research. I am also grateful to my thesis committee members, Dr. Khalid A. Al-Fossail and Dr. Hasan S. Al-Hashim, for their valuable suggestions and comments.

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Lastly, I am deeply indebted to my friends and colleagues at KFUPM (Hasan in particular), who made my stay here a memorable experience.

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THESIS ABSTRACT

Full Name of Student : **Irfan Sami Khan**

Title of Study : **Investigation of Horizontal Well Performance Using Hele-Shaw Model**

Major Field : **Petroleum Engineering**

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The production performance of horizontal wells under three different drive mechanisms is investigated by conducting experiments on a two-dimensional Hele-Shaw model. These drive mechanisms are that of bottom-water, gas-cap and simultaneous bottom-water and gas-cap drives.

The results show that more oil is recovered for lower production rates and for the wells located farthest from the water/oil interface for bottom-water drive. For gas-cap drive, oil recovery is higher for higher production rates as long as no significant coning of gas is produced. The wells should again be located farthest from the gas/oil interface. In the case of simultaneous bottom-water and gas-cap drive, oil recovery is still higher for higher production rates if no prominent gas or water cone develops. But the well location is closer to the water/oil interface as compared to the gas/oil interface for recovering more oil.

It is concluded from the results that the simultaneous bottom-water and gas-cap drive gives the best possible scenario for oil recovery from horizontal wells at a higher production rate in a shorter time as long as the two interfaces remain stable.

MASTER OF SCIENCE DEGREE

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ملخص الرسالة

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تاريـــخ التخـــرج : ديسمبر ١٩٩٨م

تم أجراء تجارب عديدة لدراسة أداء إنتاج الآبار الأفقية تحت ثلاثة آليات مختلفـــة باستخدام نموذج هيلي شو ثنائي الأبعاد ، والآليات الثلاثة هي : الدفع بالماء مـــن أســـفل ، والدفع بالغاز من أعلى ، والدفع بهما معا .

ولقد أظهرت النتائج أن استخلاص الزيت يزيد مع معدلات الإنتاج المنخفضـــة فـــي حالة الدفع بالماء من أسفل عند وجود البئر بعيدا عن سطح التقاء الماء بالزيت . وأما فـــي حالة الدفع بالغاز من أعلى فإن استخلاص الزيت يزيد مع معدلات الإنتاج المرتفعة مـــا لـــم يتكون مخروط غازي في اتجاه بئر الإنتاج الذي يجب أن يكون بعيدا عن سطح التقاء الغـــاز والزيت .

وعند الدفع بالماء من أسفل والدفع بالغاز من أعلى معا فإن استخلاص الزيت يزيـــد مع معدلات الإنتاج المرتفعة ما لم يتكون مخروط مائي وغازي ، ولكن يجب أن يكون لابـــئر أقرب إلى سطح التقاء الماء والزيت منه إلى سطح التقاء الغاز والزيت وذلـــك لاســـتخلاص أكبر أكبر كمية ممكنة من الزيت .

ويستخلص من نتائج الدراسة أن الدفع بالماء من أسفل والدفع بالغاز من أعلى معـــا هي أفضل طريقة ممكنة لاستخلاص الزيت من الآبار الأفقية عند معـــدلات الإنتـــاج العاليـــة طالما ظل سطح التقاء الماء والزيت ، وسطح التقاء الغاز والزيت مستقرين .

دراسة ماجستير العلوم

جامعة الملك فهد للبترول والمعادن

الظهران - المملكة العربية السعودية

ديسمبر ١٩٩٨م

Chapter 1

INTRODUCTION

The rate of oil production from a reservoir is controlled by pressure gradients. Most of the pressure drop in conventional wells occurs near the well because of the convergent flow (figure 1.1). It is necessary to reduce the resistance to flow within the reservoir particularly near the well-bore region in order to increase the production rate. This can be accomplished by drilling multiple wells and placing them evenly throughout the reservoir. This approach reduces the near well-bore resistance by increasing the total availability of contact area between the reservoir and the producing well-bores and also decreases the average distance that the fluids have to flow

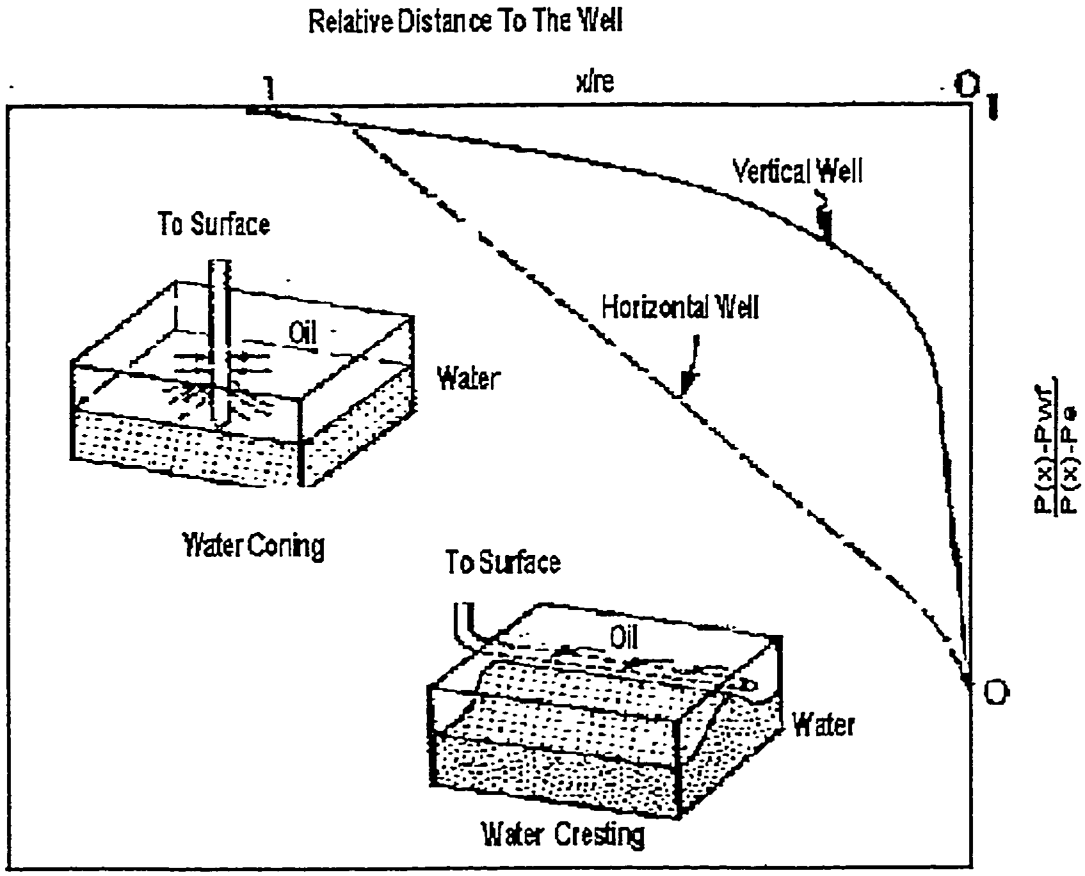

Figure 1.1: Pressure decline for vertical and horizontal wells [26]

before they are produced. In this regard, the use of horizontal wells which penetrate the reservoir in a horizontal rather than a vertical direction provides a better means of improving contact with the reservoir. They are usually drilled from the surface using deviated drilling techniques. Fewer horizontal wells are needed to achieve the same reservoir drainage as compared to vertical wells because of decreased resistance to flow around an extended horizontal section and a larger contact area with the reservoir.

The recent developments in horizontal-well technology have shown that horizontal wells can improve the efficiency and economy of oil recovery operations considerably. The long well-bores with longer completed intervals allow higher production rates to be achieved without causing serious coning problems. Horizontal wells have proved particularly beneficial in reservoirs having low productivity, vertical fractures, water and gas coning limitations and those having thick, heavy bitumen where steam assisted gravity drainage could be a practical option.

The major disadvantage of horizontal wells is that only one pay zone can be drained per well. But this problem can be resolved by using 'staircase type' wells with long horizontal portions in more than one layer, by creating vertical fractures perpendicular to the wells intersecting more than one pay zone or by drilling multi-lateral wells from the same vertical hole. Another disadvantage of horizontal wells is their higher cost as compared to that of vertical wells. It costs about 1.5 times more for a horizontal well than a vertical well drilled in similar conditions. But, considering the fact that a single horizontal well can replace a number of vertical wells to produce the same segment of a reservoir makes it more economical at the end. Reservoir heterogeneities and damage can restrict the fluid flow in the well-bore in some portions of the completed interval and thus pose another disadvantage for the horizontal wells.

There are many reservoirs in the world that have either an active water layer below the oil zone, or a gas cap above it, or both. Oil production from such reservoirs causes the oil-water interface and/or the gas-oil interface to move towards the production well. The interface becomes curved and with conventional wells assumes a shape resembling that of a cone. In such cases, the near well-bore resistance to flow results in high horizontal pressure gradients that can lift the water upwards to the well or draw the gas-cap downwards resulting in early breakthroughs. As it allows by-passing of free gas or water, coning creates serious inefficiencies leading to loss of production, lower oil cut, poor sweep of the reservoir and lesser recovery of oil in place.

The use of horizontal wells to enhance oil production from water-drive reservoirs has been widely appreciated around the world. Influx to the well is significantly increased due to the larger area of the well-bore exposed to the reservoir. Therefore, a horizontal well requires a lower draw-down for a given rate resulting in longer water breakthrough time. The improved oil recovery that is obtained through the use of horizontal wells depends on many factors such as the length of the horizontal section opened, rate of production, position of the well-bore in the oil zone, etc. If the flow rate is low then the pressure gradient is insufficient to lift the water to the production well and water-free recovery is possible. When the progress of the interface is known, it is possible to calculate the values of the recovery ratio at any stage of the process. This knowledge makes it possible to select the optimal strategy of a recovery process.

In reservoirs overlain by a gas-cap, oil production causes the gas-oil interface to curve downwards as it advances towards the producer. With conventional wells, the rate of production required for the operation to be economic is usually too high to avoid production of free gas. However, with horizontal wells, the critical production rate is higher and may allow economically feasible operation without gas production. A stable interface can be maintained much closer to the well giving higher recoveries for comparable rates.

In reservoirs with both bottom-water and gas-cap, the analysis of the well performance and the determination of optimal production rates without water/gas production become more difficult.

The present work is an experimental investigation directed towards achieving a better understanding of horizontal well performance in a bottom-water, a gas-cap and, more importantly, a combined bottom-water and gas-cap drive.

Chapter 2

LITERATURE REVIEW

Ever since Musket presented his approximate theory on water coning in 1935, the primary research focus has been on design and performance optimization. Subjects such as critical production rates, time for the cone to break-through and production after break-through have been studied with physical, analogue, analytical and numerical simulation models.

In this regard, the performance of horizontal wells for various reservoir and production conditions has been studied widely in recent years. These research studies investigated the critical flow rates, break-through times, well productivity, water-cut data and the optimal well location. For the evaluation of these parameters, mostly analytical and numerical techniques were used.

Some researchers did conduct experimental studies to analyze the performance of horizontal wells, especially for studying interface movement and the different factors that affect it.

A comprehensive review of the petroleum literature about the reservoir and petroleum engineering aspects of the horizontal wells was presented by **Noris et al**[1] and **Butler**[2]. They provided an overview of the theoretical as well as the practical areas related to horizontal wells such as critical rate, coning problem, well-test analysis, hydraulic fracturing, thermal recovery, drilling techniques, production scenarios and cost and feasibility. A review of the literature is presented below emphasizing the areas related to current research.

2.1 Productivity And Flow Characteristics

Different authors have presented their findings of horizontal well behavior and productivity for various reservoir conditions. For example, **Giger**[3] examined the role of horizontal well technology in the development of low permeability reservoirs under steady-state flow conditions for both homogeneous and anisotropic environments. His results showed that horizontal wells are well suited for thin reservoirs with a good vertical permeability, based on a productivity comparison with vertical wells under similar conditions. Similarly, **Ozkan** and **Raghavan**[4] conducted a comparative study of a horizontal well with a fully penetrating vertical fracture and discussed the corresponding pressure behavior. Their analysis was based on two classical boundary conditions of infinite conductivity and uniform flux and the results indicated that the productivity is governed by the well-length and well-radius. Another analytical study to calculate the productivity of a horizontal well for pseudo-steady state conditions was made by **Babu** and **Odeh**[5]. They concluded that the well length and its degree of penetration have the strongest effect on the productivity of the well. **Kuchuk et al**[6] presented a method to interpret the horizontal well pressure transient tests to analyze the pseudo-synthetic and real well test data. Their findings indicated that a drawdown test followed by buildup test would produce satisfactory results for the estimation of reservoir performance for horizontal wells if down-hole flow rate and pressure are measured. A simple analytical method was developed by **Dikken**[7] to link the single-phase turbulent well flow to the stabilized reservoir flow. The resulting scheme was solved numerically and it was concluded that turbulent well flow in horizontal sections might result in an appreciable reduction in drawdown at positions farther away from the start of the section. It was observed that if gas/water cresting is the limiting factor for producing the well, then the reduced drawdown farther down the hole will cause less oil to be displaced by gas/water at these positions as compared to positions near the start of the section.

2.2 Critical Rate & Break-Through Time

One of the main advantages of horizontal wells over vertical ones is that the pressure drop near and around the well bore is very low as compared to that around a vertical well-bore. Due to this low-pressure drawdown, high production rate is expected without coning. Various critical rate correlations for horizontal wells can be found in the literature [8,9,10,11,12]. **Yang** and **Wattenberger**[12] have presented a comprehensive method to calculate the critical rates, break-through times and the WOR after break-through in both vertical and horizontal wells. Break-through time and WOR are also important parameters because it is not always economical to produce below critical rates. **Ozkan** and **Raghavan**[13] studied analytically the pressure behavior of horizontal wells and developed a theoretical correlation to calculate water break-through time assuming a bottom-water drive reservoir to represent a constant pressure boundary in their calculations. **Papatzacos et al**[14] presented their results on break-through time in a horizontal well placed in a reservoir in either bottom-water or gas-cap or both. They used two semi-analytical models to solve this problem based on two separate assumptions of (i)constant pressure boundary and (ii)gravity equilibrium in the cone. Their method predicted single-cone gas or water, and two-cone gas and water breakthrough times in horizontal wells completed in the oil zone. These dimensionless solutions represented a condensed engineering method for screening horizontal well prospects, prior to detailed simulation studies. The detailed simulation studies showed the theory to be valid for low theory to be valid for low dimensionless rates, when the time to breakthrough is sufficiently long to be of practical interest.

2.3 Coning Evaluation

Water and gas coning is a major issue in petroleum engineering. In the case of horizontal wells this problem is significantly reduced because of the longer exposed well-bores and lesser drawdown pressures between the reservoir and the well bore. For horizontal wells, coning is referred to as 'cresting' for water and 'cusping' for gas (figures 2.1 and 2.2). **Singhal**[15] conducted a very unique and extensive technology overview of the coning problem. He found out from his research that several technologies for designing, operating and predicting performance under coning conditions have been developed. Many new approaches to coning mitigation seem to be promising but still are largely unproven. Horizontal wells present a potential solution to reservoir related problems but are restricted by the currently available completion techniques. **Permadi**[16] also presented a new method for fast horizontal well coning calculation based on the application of linear displacement concepts. To account for both non-uniform flow and flow geometry, a factor that contains drainage area, well length and well position is introduced. The effect of relative permeability characteristics on coning behavior was also investigated. The results showed that the production

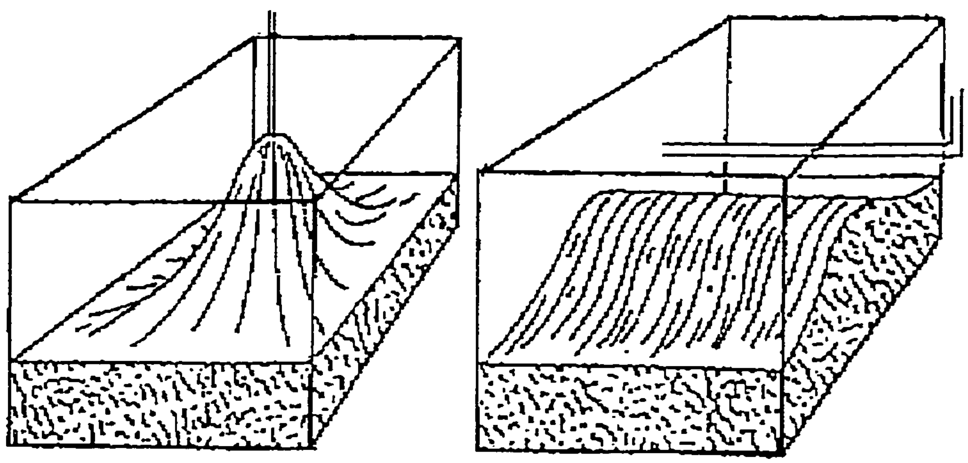

Figure 2. 1: Coning and Cresting in Vertical and Horizontal Wells [26]

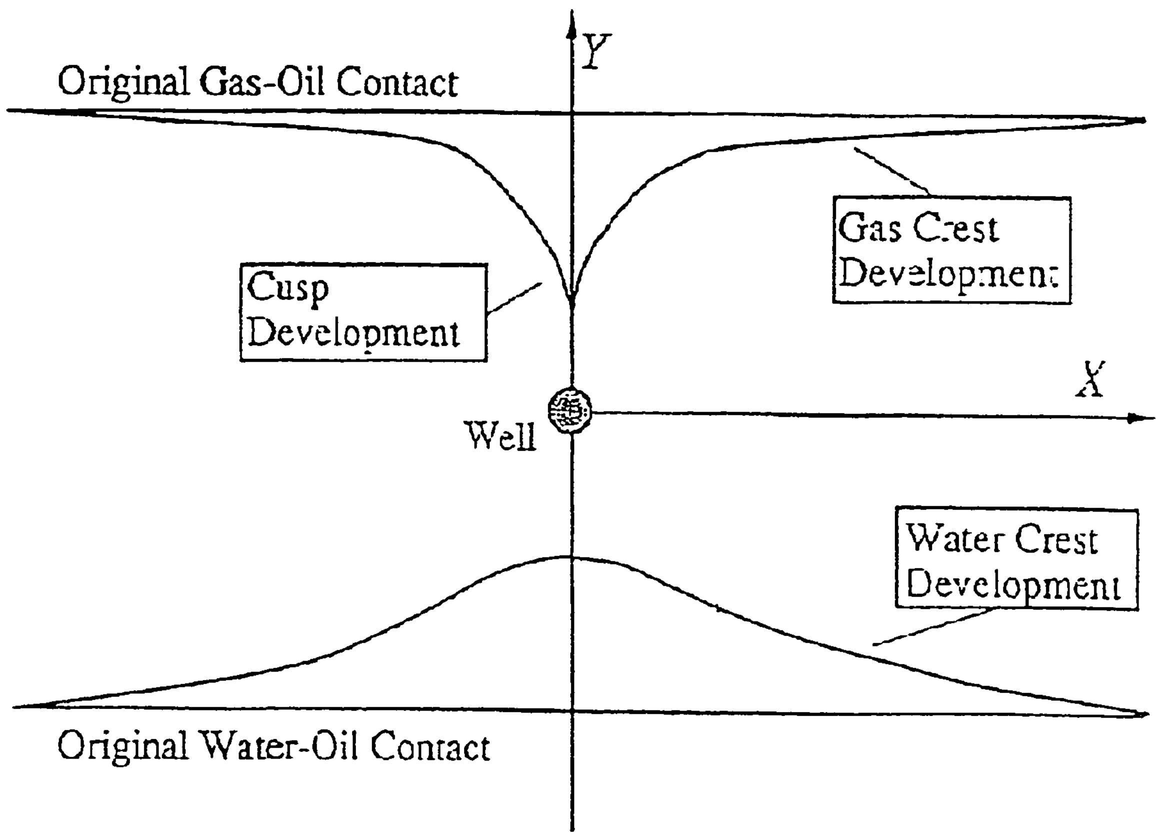

Figure 2. 2: Water and Gas Crest Development in Horizontal Wells [14]

performance of a horizontal well in a bottom-water drive is strongly influenced by the end-point mobility ratio and position of the well bore with respect to the water/oil contact. **Piteraru**[17] presented an analytical method for gas and water coning evaluation for vertical and horizontal wells. He also gave an analytical correlation for the recovery factor and stated that it mainly depends on well position, well perforation, oil-rate, anisotropy and cappilarity.

2.4 Recovery Performance And Interface Movement

Supronowicz and **Butler**[18] used the potential distribution and streamline theory to analyze oil production from reservoirs underlain by an active acquifer. The main objective of their study was to describe the progress of the interface between oil and water phases. They studied the effect of recovery ratio, break-through time and geometry of the potential field and the relationship between them on the process of oil recovery and presented ways to optimize it. They presented a mathematical model for doing this, which was based on the assumption of equality of densities and mobilities of both reservoir fluids. They observed that the model was even applicable for small density and viscosity differences. The only factor on which the progress of the interface depended was the well spacing to reservoir thickness ratio. The shape of the water crest created by a horizontal well was modeled analytically by **Giger**[19]. He considered three production mechanisms; lateral-edge drive, gas-cap drive and bottom-water drive. He determined theoretically, the best position for a horizontal well with respect to its production rate for the gas-cap drive with an under-lying non-active acquifer. He also claimed that the critical flow rate decreases with the cumulative production for the bottom-water drive mechanism. **Aulie** and **Asheim**[20] investigated the cresting phenomenon and the critical flow rate for horizontal wells, experimentally and analytically. For bottom-water drives, the analytical model provided a reasonable prediction at low flow rates, but deteriorated at higher rates. For edge-water drive, the developed model predicted the measured steady-state supercritical production performance over a wide range of flow rates. Hele-Shaw cell experiments were conducted by **Butler** and **Kanakia**[21] to examine the effects of production rate, well spacing, initial height of the reservoir and the types of the fluid on the recovery for downward displacement of oil by gas to horizontal wells situated at the base of the reservoir. They found that the interface became unstable at flow rates higher than the critical rate and that the recovery is improved if the rate is just below the critical rate. Closely spaced wells and higher initial height of the reservoir also helps in improving oil recovery. **Meszaros et al**[22] investigated the possibility of using horizontal well to achieve gravity stabilization by placing it on top of the reservoir and producing through another horizontal well at the bottom while injecting gas. A series of partially scaled 2-dimensional model studies indicated that close to 70% oil in place might be recovered by using gas injection from the top of a heavy oil reservoir of oil viscosities of 1000 and 4000 mPa.s. Two more runs using lower oil viscosities were conducted with high-pressure geometrically scaled physical models. It was found that it was much harder to maintain a stable gas front in a geometrically scaled, high-pressure, 3-dimensional model than in a partially scaled 2-dimensional model. It was concluded that if the frontal stability was lost, gas injection did not increase oil production beyond that of a primary depletion case. The presence of CO_2 as opposed to nitrogen improved recovery to some extent. **Butler** and **Jiang**[23] presented an experimental study related to bottom water coning flow to a horizontal well. They investigated the stability of water-oil interface at different flow rates and viscosity ratios. It was found that the interface remained stable and the recovery was high for low flow rates and for water and oil having same viscosities but as the flow rates and/or viscosity ratios increased the interface became unstable. However, in some cases when multiple fingers formed for high flow rates and high viscosity ratios, the oil recovery was even higher than that for lower flow rates. The piston type displacement found in Hele-Shaw cells, was simulated numerically to predict the advancement of the water-oil interface, oil recovery and pressure behavior. This analysis was found to be in agreement with the experimental results. **Permadi** and **Abdassah**[24] used a physical model representing two-dimensional observation to study water cresting and oil recovery from horizontal wells in the presence of impermeable streaks in a reservoir. Their results showed that the bottom water breakthrough point through a well depended on the well-bore flow direction, non-uniform influx occurred above critical rates and oil recovery increased when the heel end of the long horizontal well is located above the upper layer of the streaks. **Butler** and **Jiang**[25] studied the effect of gravity on the movement of the water-oil interface and on the oil recovery, experimentally and theoretically. Two sets of experiments were carried out in a Hele-Shaw cell. They found out that the oil recovery at breakthrough decreases if the flow rate is increased. Furthermore, if the interface was allowed to fall under the effect of gravity alone, it fell at the center and rose at the two ends and became progressively flatter. Analytical and numerical studies were also used to predict the movement of the fluids that were in agreement with the experimental results.

Hence, extensive work exists in the literature for the analysis of the horizontal well performance. In this regard major contributions have been aimed at finding the productivity, simulating the fluid flow, evaluating the critical rate and breakthrough time and predicting the cone shape and the interface movement. Most of this work is, however, analytical or numerical. Very few experimental studies have been conducted in this area, particularly for studying the production performance of the horizontal wells under combined water and gas drive.

Chapter 3

STATEMENT OF PROBLEM AND OBJECTIVES OF THE STUDY

The literature survey presents some rich works done in the field of horizontal wells in the recent years. However most of the research has been done to study the performance of horizontal wells theoretically and numerically, and the little experimental work that has been done, is only for either bottom-water drive or gas-cap drive mechanisms. For the case of combined bottom-water and gas-cap drive, no experimental study has been conducted to investigate the performance of horizontal wells in conventional oil reservoirs.

Thus, there is a need to investigate experimentally the performance of horizontal wells under bottom-water, gas-cap and, particularly, simultaneous bottom-water and gas-cap drives. The present research is directed towards this need. Hence, the objective of the present work is to better understand the horizontal well performance under the different drive mechanisms.

To achieve this objective, a scaled physical model (Hele-Shaw Model) is built to simulate a typical two-dimensional section of an oil reservoir. This reservoir model is produced at different production rates from different well locations for various drive mechanisms. Data collected from these experiments provides the basis for determining the best production strategy under different drive mechanisms by comparing the oil recoveries, breakthrough times, water-cuts, pressure drops and interface movements for the various producing conditions.

Chapter 4

EXPERIMENTAL SET-UP AND PROCEDURES

A Hele-Shaw model (figure 4.1) is used for the experiments in which flow takes place between two plates. The advantage of this system is that a visual observation of the interface movement can be seen clearly since the plates are transparent. Any surface effects between the matrix of the porous medium are eliminated and equilibrium conditions are established quickly. Fluids used can be changed immediately and with a little modification the production equipment can also be altered easily. The principal disadvantage of the system is that it is restricted for two-dimensional flow studies.

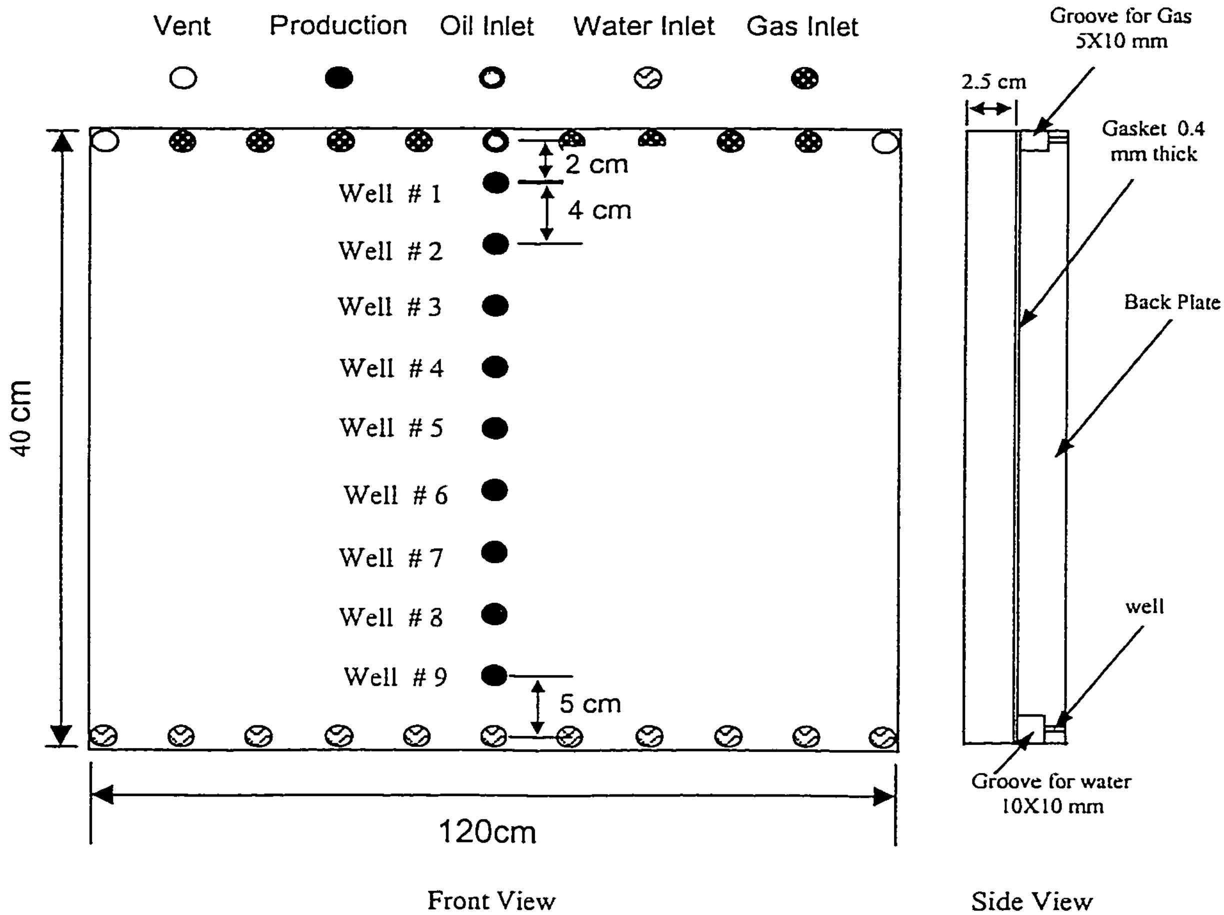

Figure 4.1: Schematic of Hele-Shaw Model

4.1 Apparatus

A detailed description of the apparatus used for the experiments is given below. Schematic diagrams of the experimental set-up for the different drive mechanisms are shown in figure 4.2.

4.1.1 Hele-Shaw Model:

The model (figure 4.1) consists of two vertical, transparent, parallel plexi-glass plates, each one inch (2.54cm) thick. The length of the model is 120 cm and its height is 40 cm. These dimensions represent scaled down values of a real field reservoir in Saudi Arabia. The space between the two plates is made as thin as possible for representing a porous medium, and is taken to be 0.04 cm, that is equal to the thickness of the gasket placed between the plates around the edges. To ensure tight boundaries and an even distance between the plates, a steel structure is placed around them and clamped together by bolts.

The production wells are represented by small holes (diameter of 1/8") drilled into the back plate and evenly spaced along the center of the plate. Figure 4.1 shows the locations of these wells on the model and the respective distance between them. They are numbered from 1 to 9 starting from top. Holes provided at the top and bottom portion of the plate are used as injection ports for gas and water respectively. These open into two grooves on the inside of the plate to dampen any pulsation effects. The middle port at the top is used as an oil inlet and the two at the corner as vents to remove any air bubbles from the model.

4.1.2 Fraction Collector:

An ISCO fraction collector is used to collect the production fluids in 10 cc test tubes. The fraction collector can be set to move according to time. In this way the volume collected in a certain time can be recorded.

4.1.3 Water and Gas Storage Systems:

Two different mechanisms are used to represent the water storage system during the experiments as shown in figure 4.2 . For bottom-water drive experiments, water is introduced into the lower portion of the model by injecting it through an injection pump [figure 4.2 (a)]. The water is allowed to rise in the model upto a height of 4 cms from the bottom. At this level the initial water/oil interface is established and then fixed for all experimental runs.

For the simultaneous bottom-water and gas-cap drive [figure 4.2 (c)], bottom-water drive is represented by placing a water reservoir at the bottom of the plates. This water reservoir continuously receives water supply from a water tank placed at a height of 41 inches (104.14 cm) above the water oil contact. The position of the initial water-oil contact in the model is always fixed at 4 cm from the bottom of the model. The head is kept unchanged by

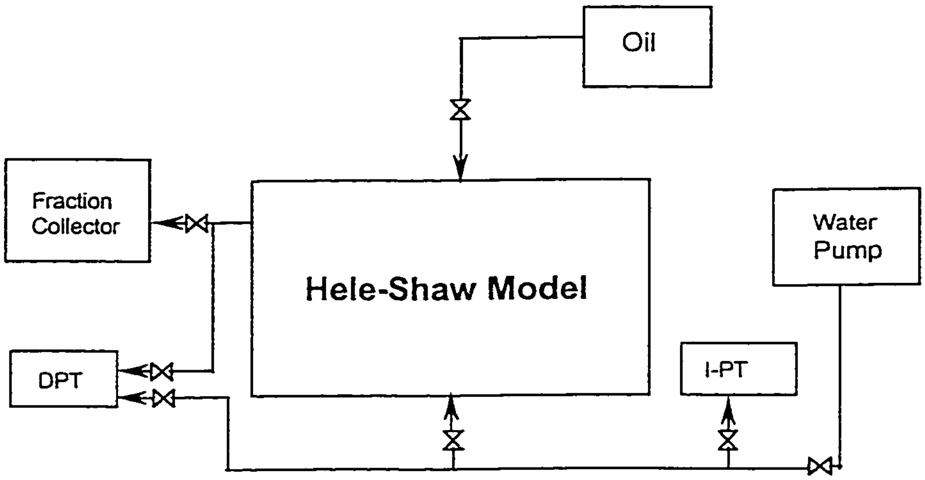

Figure 4.2 (a): Schematic of Experimental Set-Up for BWD

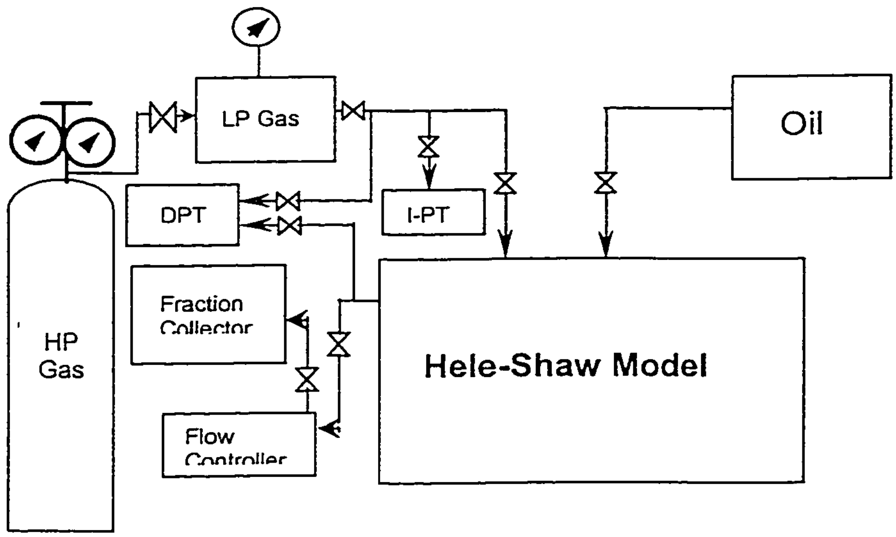

Figure 4.2 (b): Schematic of Experimental Set-Up for GCD

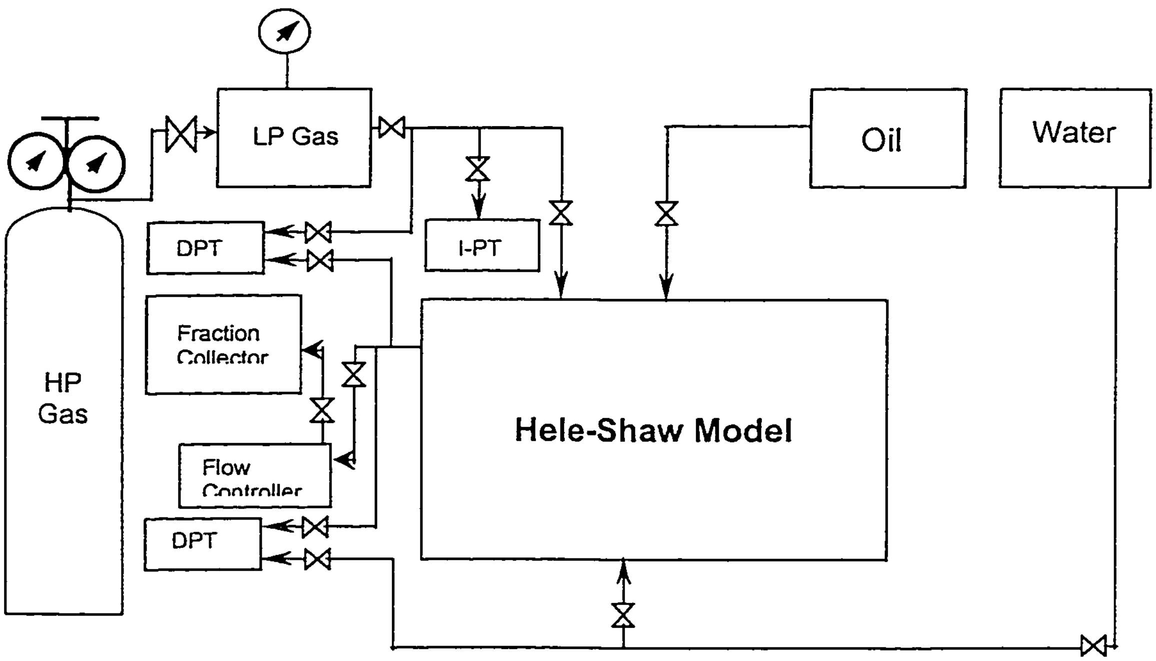

Figure 4.2 (c): Schematic of Experimental Set-Up for SWGD

constant level control mechanism involving refilling of the water tank continuously. At this height of 41 inches, the water creates a pressure head of 3.4 psig at the point of water/oil contact. This is calculated as follows:

Since,

$$P(\text{psig}) = 0.052 \times \rho(\text{lbs/gal}) \times h(\text{ft})$$

But ,

$$1 \text{ lb} = 453.59 \text{ gms}$$

$$1 \text{ gal(US)} = 3785.43 \text{ cc}$$

$$1 \text{ ft} = 12 \text{ inches}$$

$$1 \text{ cm} = 0.3937 \text{ inches}$$

therefore after unit conversions,

$$P_w(\text{psig}) = 0.07477 \times \rho_w(\text{gm/cc}) \times h_w(\text{inches})$$

$$P_w(\text{psig}) = 0.07477 \times 1.08(\text{gm/cc}) \times 41(\text{inches})$$

$$P_w(\text{psig}) = 3.4 \text{ psig}$$

For the 34 cm head of oil inside the model above the water/oil interface,

$$P_o(\text{psig}) = 0.07477 \times \rho_o(\text{gm/cc}) \times h_o(\text{inches})$$

$$P_o(\text{psig}) = 0.07477 \times 0.83(\text{gm/cc}) \times 34 \times 0.3937(\text{inches})$$

$$P_o(\text{psig}) = 0.85 \text{ psig}$$

Therefore the pressure of the gas at the inlet should be about

$$P_g(\text{psig}) = 3.4\text{-}0.85 = 2.55 \text{ psig}$$

2.5 psig in order to maintain equilibrium inside the model before the start of production.

Gas-cap drive is represented by a gas storage and a supply system that consists of a nitrogen gas cylinder fitted with a pressure regulator and a gauge and a gas bottle (volume 500cc) with a low pressure gauge (figure 4.2 (b)). The gas cylinder, the gas bottle and the manifold connecting the gas injection ports in the top section of the model are all connected in line with a series of steel tubings and valves. The same set-up is used for the simultaneous bottom-water and gas-cap drive also. Before starting each experiment for gas drive or simultaneous gas and water drive, the valve between the cylinder and the gas bottle is opened and the gas is allowed to fill the bottle and the upper section of the model until a pressure of just above two psig is reached. It is difficult to make this pressure exactly 2.5 psig because the valves are manually handled and the gas pressure inside the gas bottle is monitored by a low range pressure gauge of 15 psig which is still too high for the required pressure setting. Then the inlet valve to the gas bottle is closed and the system is checked for any leaks. The pressure should hold at this value until the experiment is started by opening the production valve.

4.1.4 Pressure Transducers, Digital Displays and Data Acquisition System:

Three pressure transducers are used in the system for recording the pressure distribution. Two of them are differential type (Validyne DP303 with 20 psig diaphragm for gas side and 12.5 psig diaphragm for water side), each is used to measure the differential pressure between the production point and the gas and water inlet points. The third one (Omega DP12/PX-800-010GV with 10 psig diaphragm) is just a point measuring device used to measure the injection pressure at gas inlet. Each of the transducer is connected to a digital display. The electrical signals sent by the transducers are digitized by a data translation board and sent to a data acquisition software in the computer where they are recorded every three seconds.

4.1.5 Flow-controllers:

The production rate is controlled by calibrated flow-controllers (Cole-Palmer). Two such flow-controllers are used to account for a range of 0-10 cc/min. The calibration charts for these are given in figures 4.3 and 4.4. These are based on the readings taken at various rates.

4.1.6 Camera and Recording Equipment:

Photographs are taken and video film is made to record each

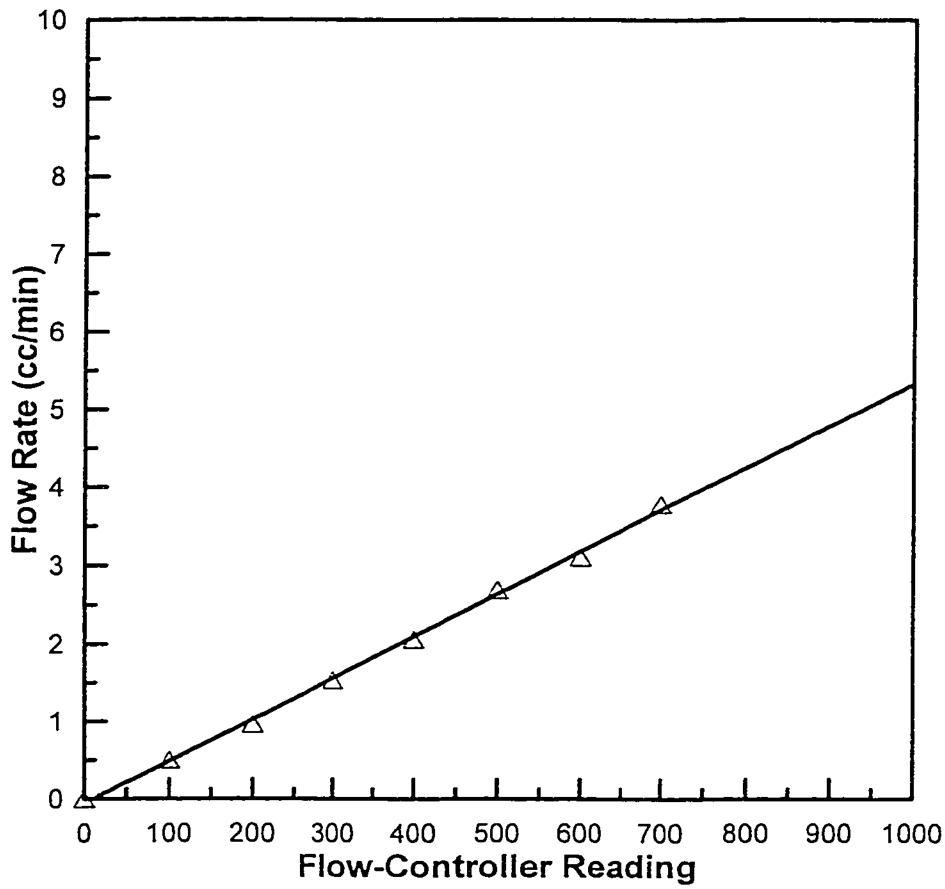

Figure 4.3: Caliberation chart for first flow-controller

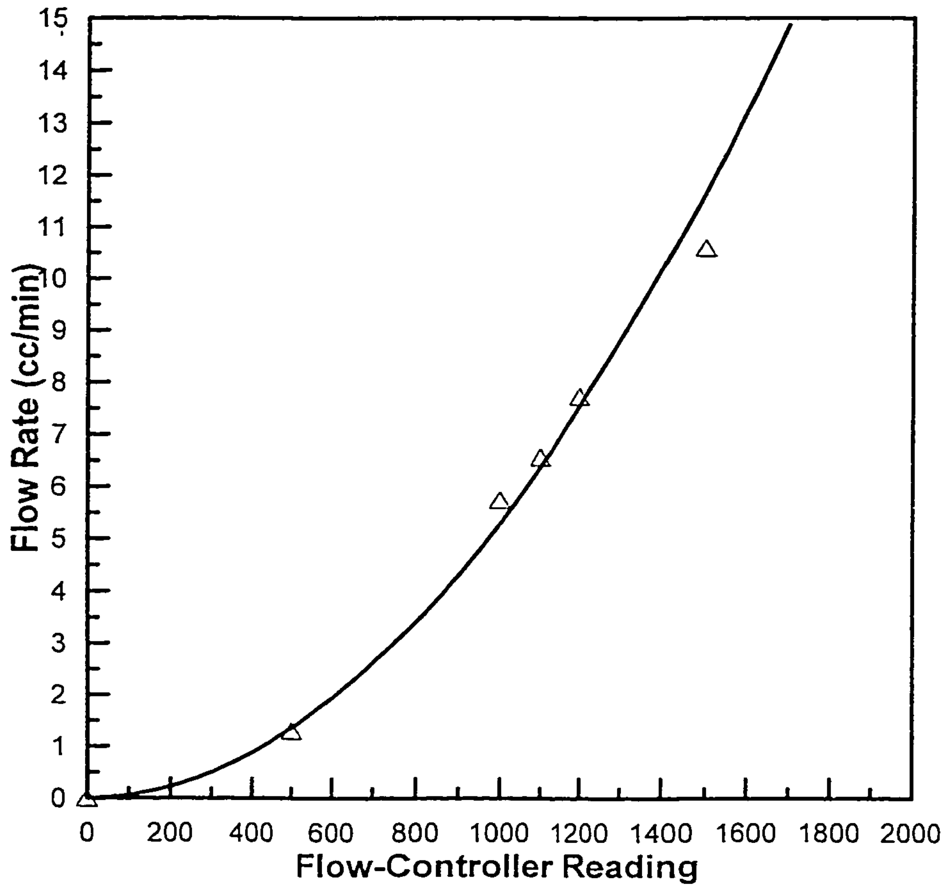

Figure 4.4: Caliberation chart for second flow-controller

experiment. This will help in defining the interface movement and the development of a possible cone. For this purpose the following equipment was used;

- Still Photographic Camera (Nikon with 55mm lens)
- Video Camera (Sony with Cannon zoom lens 11.5-69mm)
- Camera Adapter (Sony)
- Color Video Monitor (Sony Trinitron)
- VCR (Sony Multi-System)

4.1.7 Miscellaneous Items:

Tubings, fittings, shut-off valves, needle valves, pressure gauges, Ostwald's viscometer, hydrometers, stop watch, tripods, flasks, beakers, test tubes, funnels, background screen.

4.2 Fluids

Fluids used in the experiments are glycerol-water solution and nitrogen as displacing fluids and oil as the displaced fluid. The density and viscosity of the glycerol-water solution 1.08 gm/cc and 3.26 cp respectively, and those for oil are 0.83 gm/cc and 4.6 cp respectively. Water solution is colored with a green dye and oil with a red one to make visualization clear. The oil/water viscosity and density ratios were determined to simulate scaled conditions for one of the reservoirs in Saudi Arabia (refer to Table A-1).

4.3 Experimental Procedures

All experiments are started after the two phase/three phase system has reached an equilibrium condition with an approximately horizontal interface. The general procedures that follow throughout the experiments involve the following steps:

4.3.1 Preparing The Set-UP:

The set-up is first prepared for a new run. Water from the water reservoir system is allowed to rise in the model up to a height of 4 cm. Oil is introduced into the model from top and allowed to fill the model under gravity. For bottom-water drive experiments the whole model is filled with oil and any gas bubbles are removed from the top vents. For the other two scenarios, oil is filled up to 2 cm below the top of the model. The space above the oil is occupied by gas, which enters the model from the connected gas bottle. The volume of the bottle is 500 cc. So, the initial size of the gas-cap (which includes the volume of the gas bottle, the connecting valves and tubings and the upper portion of the Hele-Shaw model) is approximately 525 cc. The system is left for sometimes to stabilize and then the water/oil and the gas/oil interfaces are adjusted until they approximately reach the fixed level of 4 cms from bottom and 2 cms from top, respectively as shown in figure 4.5.

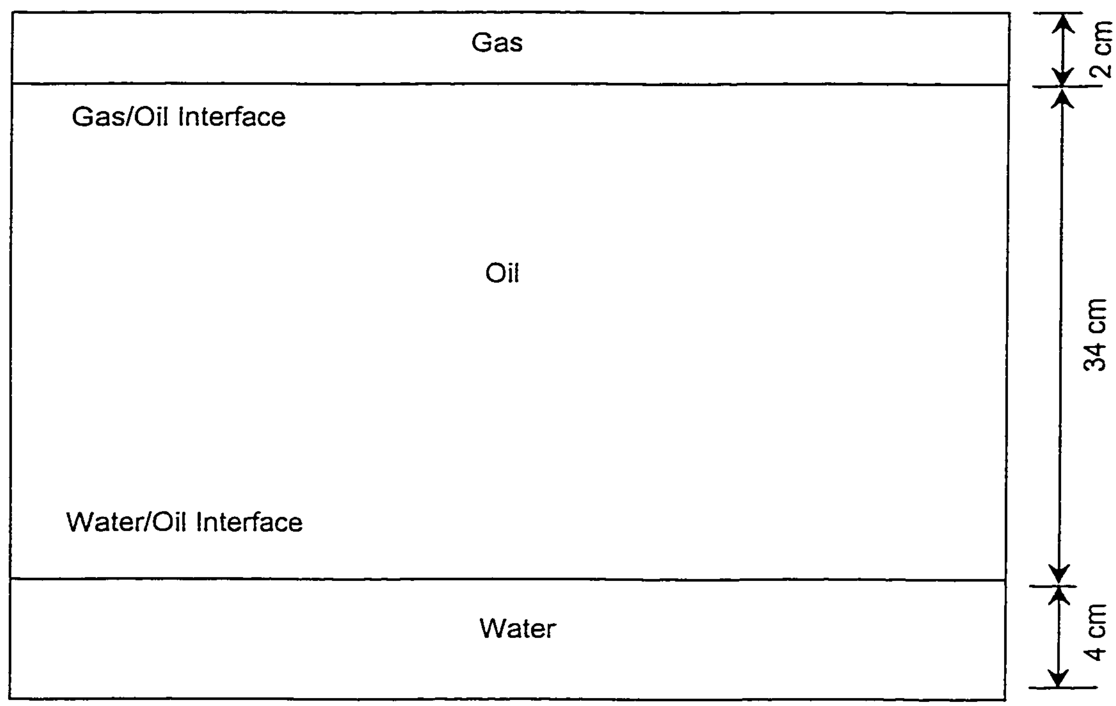

Figure 4.5: Initial position of the interfaces

4.3.2 Start-up and Production:

The experiment is started when the production valve is opened. Water or gas or both are injected through their respective ports to displace the oil already inside the cell. This oil is thus produced from the pre-set well locations at the center numbered from 1 to 9 from top to bottom (figure 4.1). The production fluids are collected in test tubes placed in the fraction collector after they have passed through the flow-controller set at a particular rate.

4.3.3 Photography and Data Collection:

Each experimental run is carefully timed by a stop watch. Photographs are taken intermittently and video film is made continuously throughout the run, from which the movement of interface can be established later on. Pressures are also recorded throughout the experiment by transducers and volumes are collected by calibrated test tubes.

4.3.4 Experiment End and Cleaning Process:

The experiments are stopped when more than 95% water-cut is obtained in case of water drive and simultaneous bottom-water and gas-cap drive or just after the break-through point in case of gas drive. After the experiment has reached its end, the injection and production valves are closed, stop watch, pressure data-acquisition program, video photography and fraction collector are also stopped. The fluid volumes collected in the test tubes are noted down and then the test tubes are drained, washed, rinsed and dried. The model is again prepared for the next run.

Chapter 5

RESULTS AND DISCUSSION

In this chapter the experimental results are presented, analyzed and discussed. These results are based on the experiments that were conducted for the following scenarios:

- Bottom-Water Drive Experiments (BWD)
- Gas-Cap Drive Experiments (GCD)
- Simultaneous Bottom-Water and Gas-Cap Drive Experiments (SWGD)

Production parameters like oil recovery, water-cut, pressure drop, breakthrough time and interface movement were obtained for each of the above production mechanisms. Comparisons of these parameters are made and the effects of different production rates and well locations on them are studied for each of the above mentioned drive mechanisms.

In all, 18 experimental runs have been selected and presented here from the numerous runs that were conducted in the laboratory. These include four for BWD, two for GCD and twelve for SWGD. More emphasis is placed here on presenting the results of SWGD because investigation of this case is the main objective of this study. The other two cases of BWD and GCD are presented here to provide supporting data and base runs for this research.

The list of these 18 runs with their respective well-locations and the production rates at which they were conducted is presented in Table 5-1. A summary of the results for these runs is presented in Table 5-2 which presents the values of oil recovery at breakthrough and breakthrough time at various production rates and well locations for the three drive mechanisms. It is important to mention here that for gas-cap drive and simultaneous bottom-water and gas-cap drive, average production rate values are presented in this table based on the total volume produced divided by the total time. For the bottom-water drive runs, when an injection pump was being used instead of a constant head water supply mechanism, the production rate is the average value based on the volume collected at breakthrough divided by the breakthrough time.

Table 5-1

List of Experiments			
Drive Mechanism	**Run #**	**Well-No. (cm from bottom of the model)**	**Average Production Rate (cc/min)**
BWD	1	1 (37.5 cm)	1.0
BWD	2	1 (37.5 cm)	1.7
BWD	3	1 (37.5 cm)	3.0
BWD	4	1 (37.5 cm)	4.7
GCD	5	8 (9.5 cm)	2.6
GCD	6	8 (9.5 cm)	5.3
SWGD	7	6 (17.5 cm)	1.0
SWGD	8	6 (17.5 cm)	2.0
SWGD	9	6 (17.5 cm)	4.0
SWGD	10	6 (17.5 cm)	7.6
SWGD	11	7 (13.5 cm)	1.0
SWGD	12	7 (13.5 cm)	2.0
SWGD	13	7 (13.5 cm)	4.0
SWGD	14	7 (13.5 cm)	7.6
SWGD	15	8 (9.5 cm)	1.0
SWGD	16	8 (9.5 cm)	2.0
SWGD	17	8 (9.5 cm)	4.0
SWGD	18	8 (9.5 cm)	7.6

Table 5-2

Results Summary						
Exp. No.	Well #	Prod. Rate (cc/min)	BT Time (min)	Rec. @ BT (%OOIP)	Total Time (min)	Max Rec. (%OOIP)
Bottom Water Drive (BWD)						
1	1	1.0	156.0	87.2	240.0	96.0
2	1	1.7	82.1	82.4	136.0	93.4
3	1	3.0	44.8	77.3	85.5	93.0
4	1	4.7	26.8	72.4	50.5	88.3
Gas Cap Drive (GCD)						
5	8	2.6	48	83.5	-	-
6	8	5.3	25	87.8	-	-
Simultaneous Bottom Water & Gas Cap Drive (SWGD)						
7	6	1.0	118.0	63.7	192.0	64.5
8	6	2.0	76.0	71.8	106.0	78.6
9	6	4.0	35.0	75.1	91.0	85.6
10	6	7.6	18.0	81.7	61.0	98.3
11	7	1.0	130.0	71.1	176.0	71.7
12	7	2.0	66.0	71.2	162.0	76.5
13	7	4.0	30.0	73.1	108.0	81.4
14	7	7.6	17.0	76.4	103.0	93.7
15	8	1.0	65.0	37.2	119.0	38.7
16	8	2.0	40.0	44.5	112.0	45.9
17	8	4.0	28.0	59.3	118.0	65.2
18	8	7.6	16.0	66.9	89.0	75.1

5.1 Bottom Water Drive Experiments (BWD)

For BWD, the well should be placed as far from the initial oil/water contact as possible. This will give the best possible well position with maximum recovery. In the present research, different well-locations near the top (well numbers 1,2 and 5) were used to study the production performance of the horizontal wells for BWD. The best well location is the top most one, that is, well # 1 because it is the farthest from the initial oil/water contact. Therefore, the results of the experiments conducted for different production rates for well # 1 are only presented here (figures 5.1 to 5.4). In these figures the oil recovery (as a percent of the original oil in place), the water-cut and pressure are plotted versus time for the four production rates investigated. Ideally, the production rate should be exactly equal to the injection rate at which the pump is set. But, due to problems with the pump, faced during the experiments, the injection rate could not be maintained constant. The reason for this was that during the initial portion of the experiment, the pump injected at a lower rate and took some time to achieve the required rate and stabilize there. This was especially true for higher flow rates. Therefore, the results that are presented here, are based on the actual fluid volumes that were produced and collected in the test tubes and not on the injection rates that were set for the pump. Table 5-2 shows the production rates for the BWD calculated on the basis of the volume of the oil that was actually produced until breakthrough during the experiments.

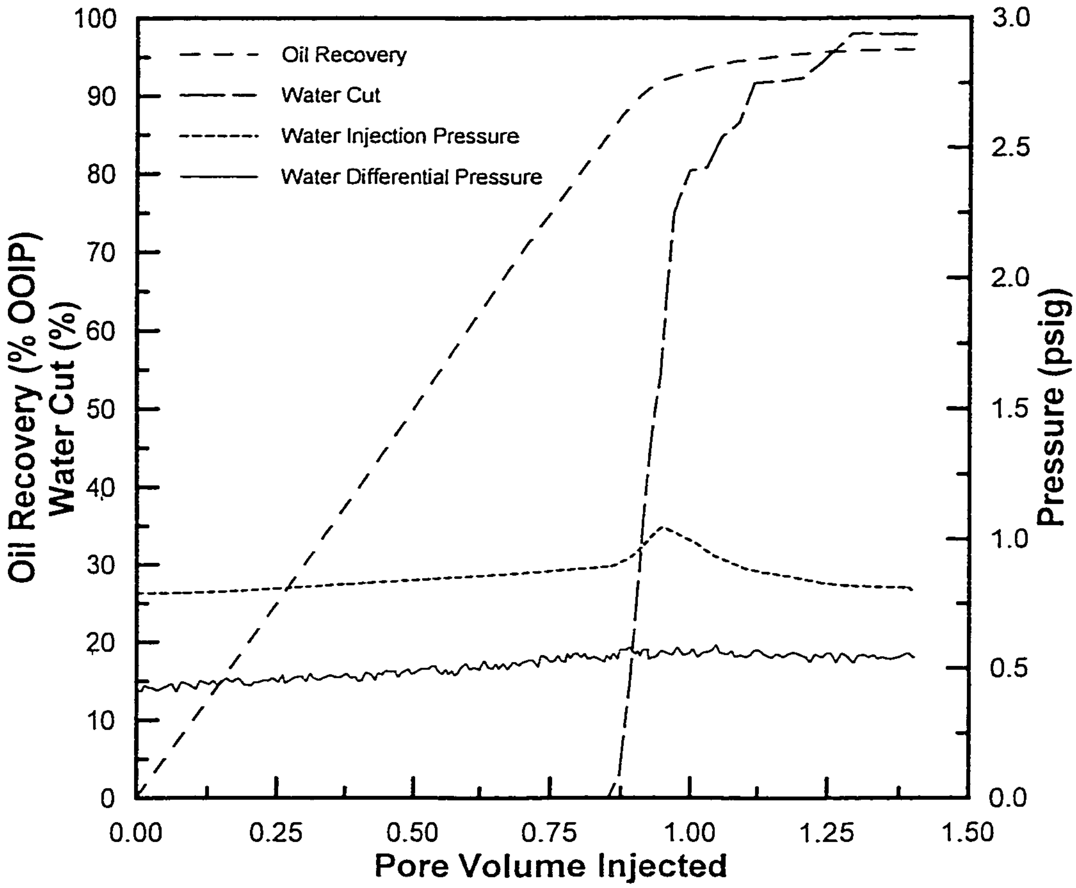

Figure 5.1: Production performance for BWD at 1cc/min from Well # 1

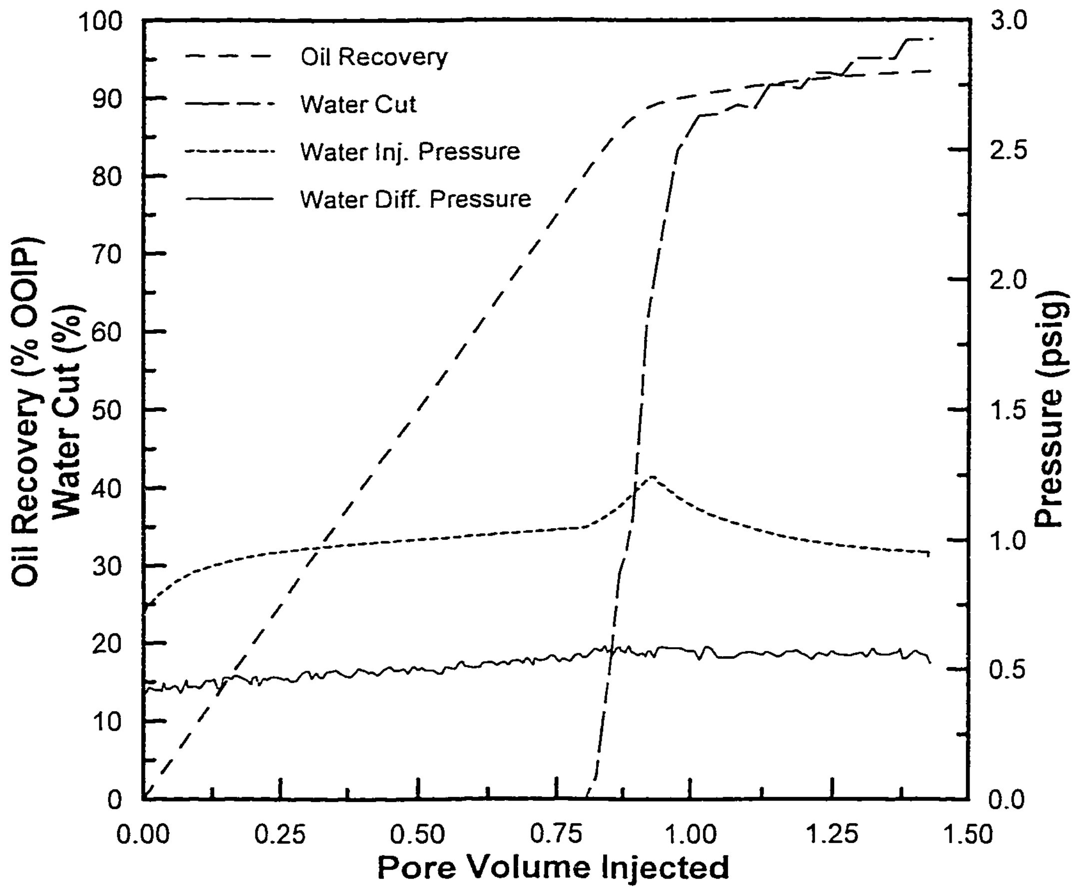

Figure 5.2: Production performance for BWD at 1.7 cc/min from Well # 1

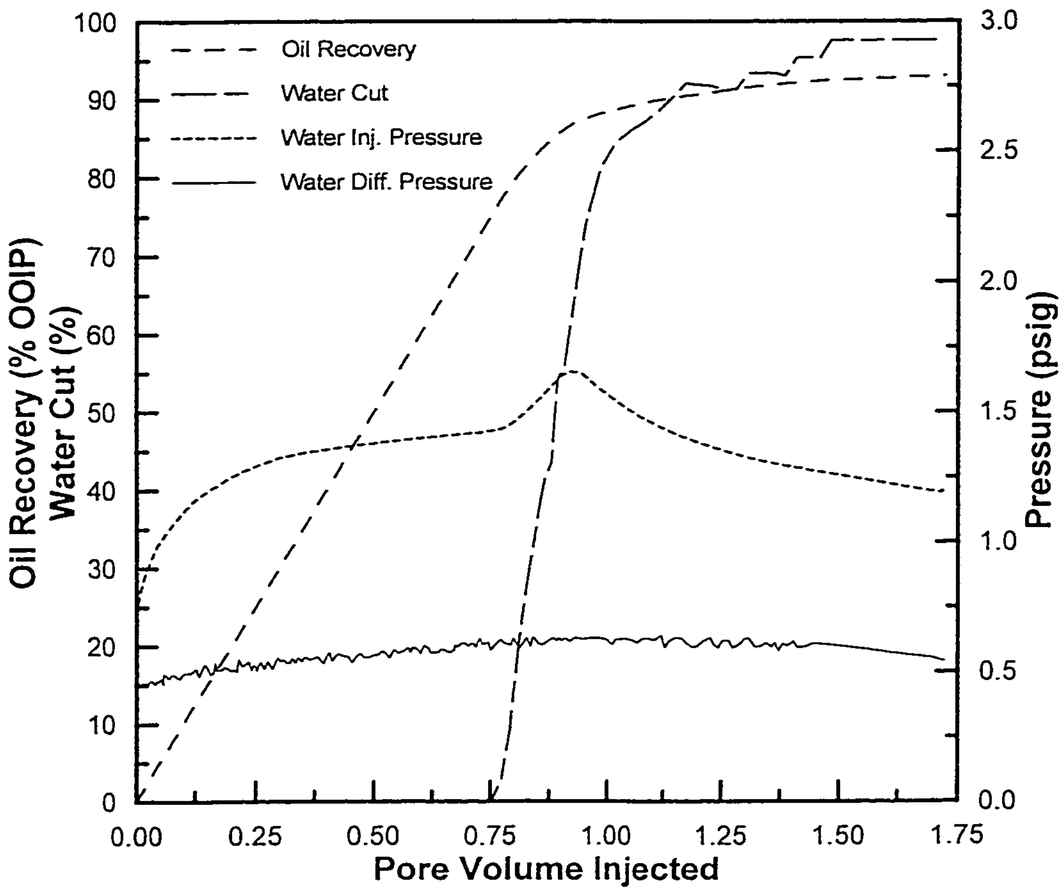

Figure 5.3: Production performance for BWD at 3.0 cc/min from Well # 1

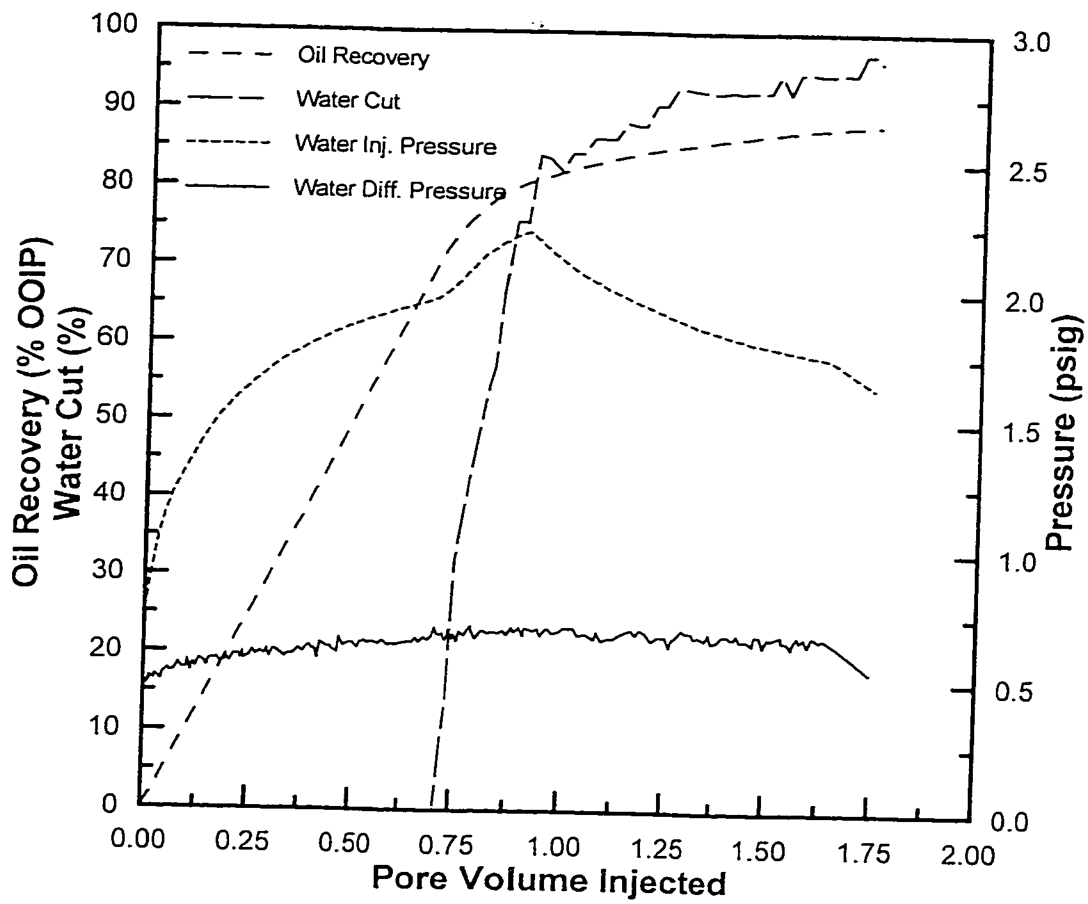

Figure 5.4: Production performance for BWD at 4.7 cc/min from Well # 1

5.1.1 Oil Recovery

A comparison of oil recovery versus time for different production rates is presented in figure 5.5. It can be seen from this figure that oil recovery gets higher as the production rate decreases. This is because at higher rates the water front approaches the well very fast and due to the higher pressure drop it cones towards the well giving an early breakthrough. Thus most of the oil is left behind and not recovered for higher production rates.

A closer observation also shows that the relationship is linear for all the four production rates until water breakthrough. After breakthrough the recovery relationship almost becomes flat and there is a large drop in the gradient. This means that most of the oil is recovered before breakthrough regardless of the production rate. As seen from figure 5.5, the lower the rate, the higher is the ultimate recovery because the actual breakthrough is delayed for lower production rates and thus there is more time available for a larger portion of oil to be recovered. At the time of breakthrough (figure 5.6), the oil recovery is 87.2% of original oil in place (OOIP) at 1cc/min, 82.4% at 1.7cc/min, 77.3% at 3cc/min and 69.8% at 4.7cc/min. Therefore, at 1cc/min about 17.4% more oil can be recovered than that at 4.7cc/min. But after the breakthrough, the maximum recoveries that are obtained for 1cc/min and 4.7cc/min are 96% and 88.3% respectively. This means that only 7.7% more oil is recovered for lower production rate after breakthrough. After the breakthrough as water-cut increases water becomes the continuous phase

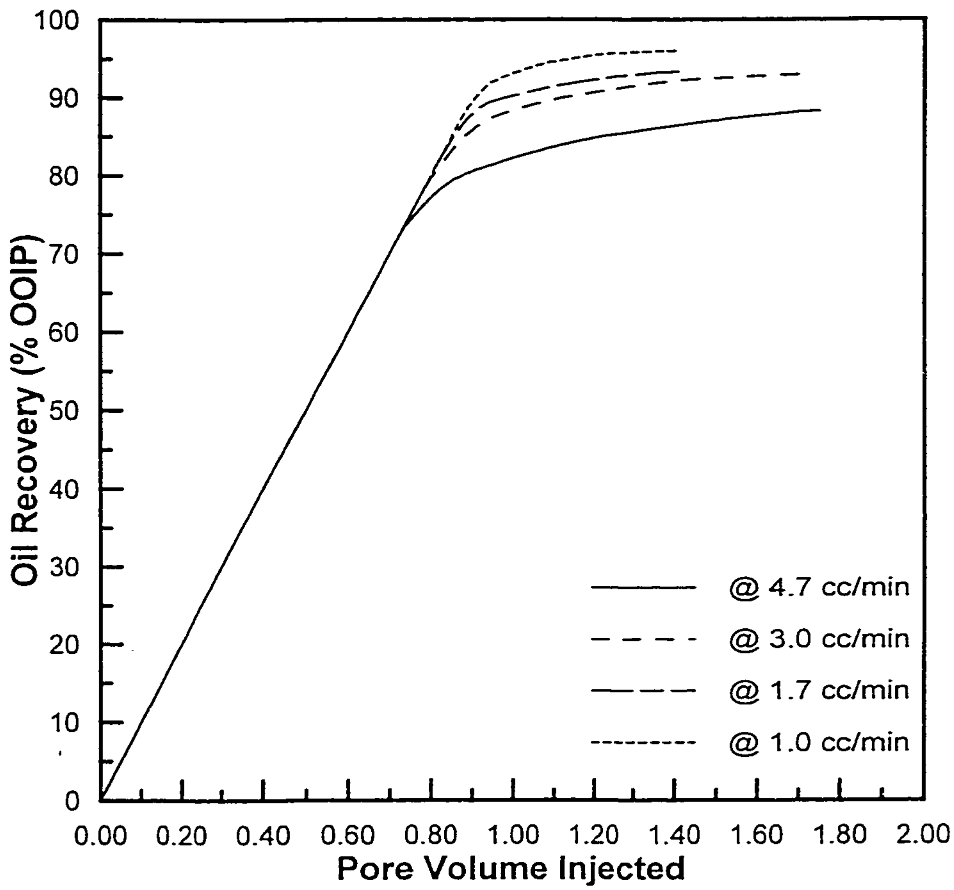

Figure 5.5: Oil Recovery Comparison for BWD from Well # 1

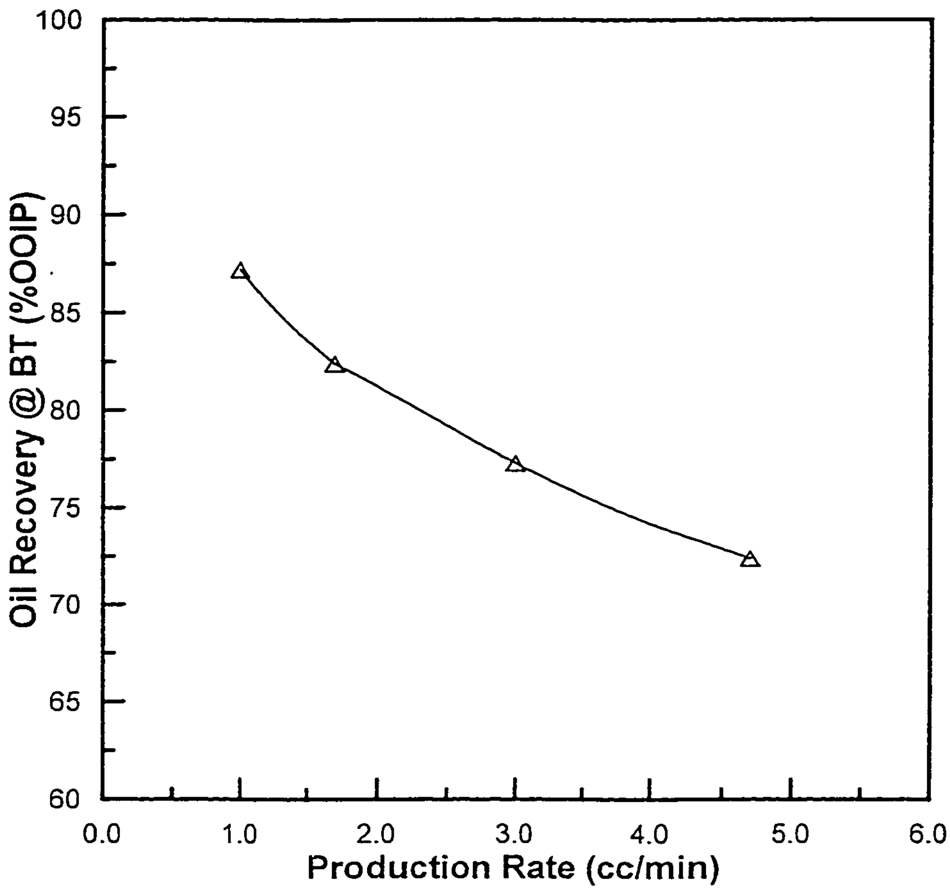

Figure 5.6: Oil Recovery at Breakthrough for BWD from Well # 1

and oil the discontinuous one. Therefore there is not as much increase in oil recovery after breakthrough for lower production rates, as it was before breakthrough.

5.1.2 Breakthrough Time

Table 5-2 presents the values for the breakthrough time for the four runs. At 1 cc/min, water breakthrough occurs at 156 minutes while at 1.7 cc/min, 3.0 cc/min and 4.7 cc/min it occurs at 82, 45 and 27 minutes, respectively. Therefore as the production rate increases, breakthrough time decreases. This is because the approaching water/oil interface advances at a faster speed at higher production rates and thus breaks through earlier through the well.

5.1.3 Water-Cut

Figures 5.7 and 5.8 compare the water-cut for different flow rates as a function of time and oil recovery, respectively. It is observed from these figures that the increase in water-cut varies for each production rate. At the lowest production rate, 1cc/min, the first ten minutes after breakthrough show an increase of about 35% in water-cut, while at 4.7cc/min for the same duration it is about 86%. Therefore, at higher production rates the increase in water-cut is very sharp as compared to that at lower rates, which causes an increased water production and reduced oil recovery.

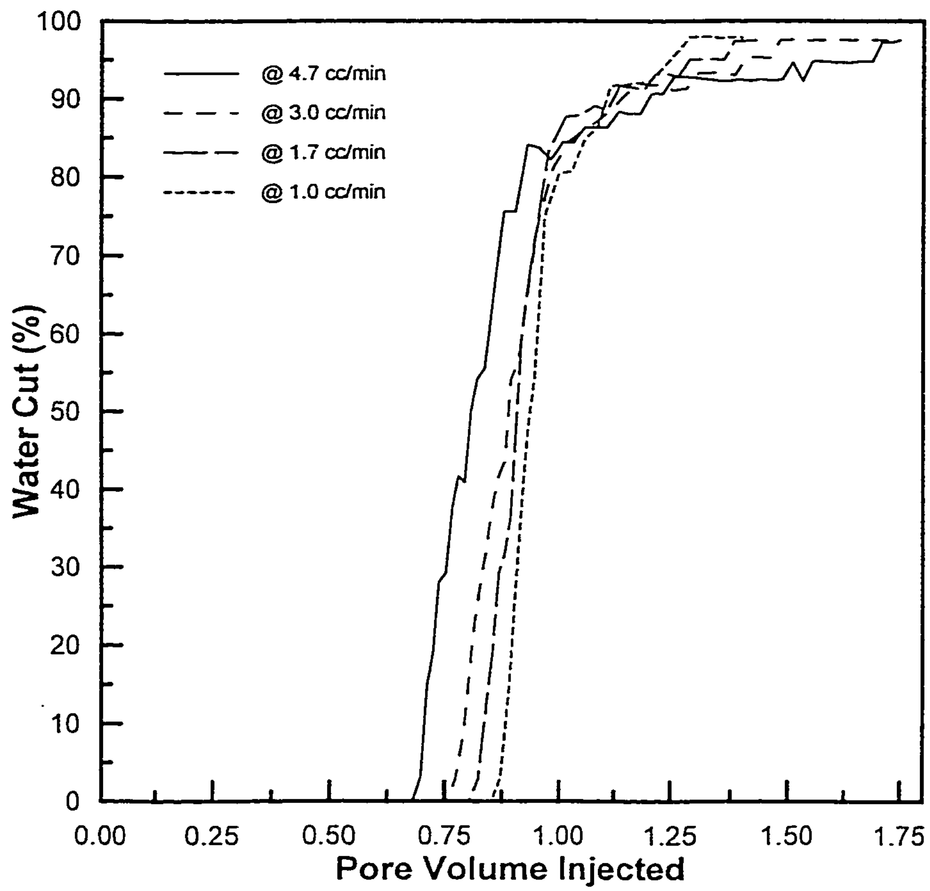

Figure 5.7: Comparison of Water Cut VS Pore Volume Injected for BWD from Well # 1

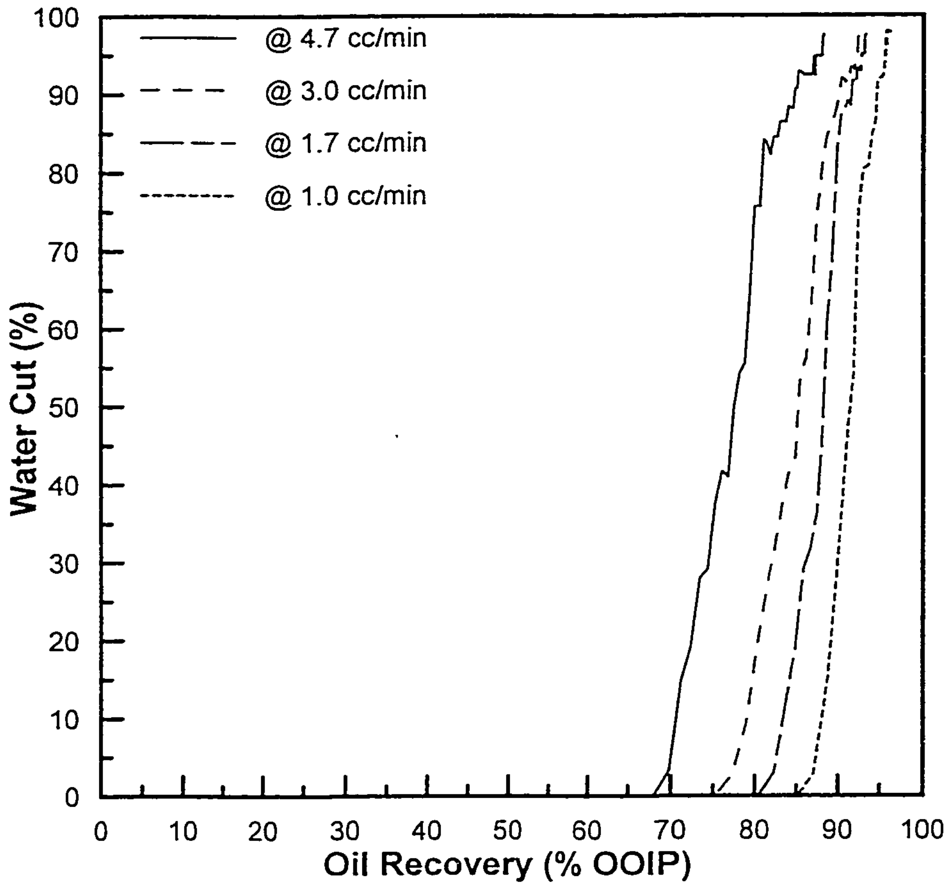

Figure 5.8: Comparison of Water Cut VS Oil Recovery for BWD from Well # 1

5.1.4 Pressure Distribution

The injection pressure and the differential pressure distributions for the four production rates are shown as a function of time in figure 5.9. Initially, the system is at static equilibrium with the oil/water contact at 4 cms from the bottom of the model. The injection pressure at this point is about 0.75 psig and the differential pressure is approximately 0.4 psig for the four runs. This initial pressure is due to the static head of oil column above the point of measurement. Once the water is injected into the model and production is started, the injection pressure increases gradually until water breakthrough. At breakthrough it rises sharply to 2.25 psig and 1.1 psig for 4.7 cc/min and 1.0 cc/min respectively.

The differential pressure also shows a slightly increasing trend until water breakthrough and continues on the same pattern until 85% water-cut is reached. Then it starts to decrease and continues to do so until the experiment is terminated. As the water-cut increases and water becomes the continuous phase, the pressure drop reduces. But these variations in differential pressure distribution are very minute, in the present experiments, and the overall trend appears to be almost constant.

5.1.5 Interface Movement

The advancement of the water/oil interface for each of the four runs for BWD is shown in figures 5.10 to 5.13. The production well (well # 1 at 37.5

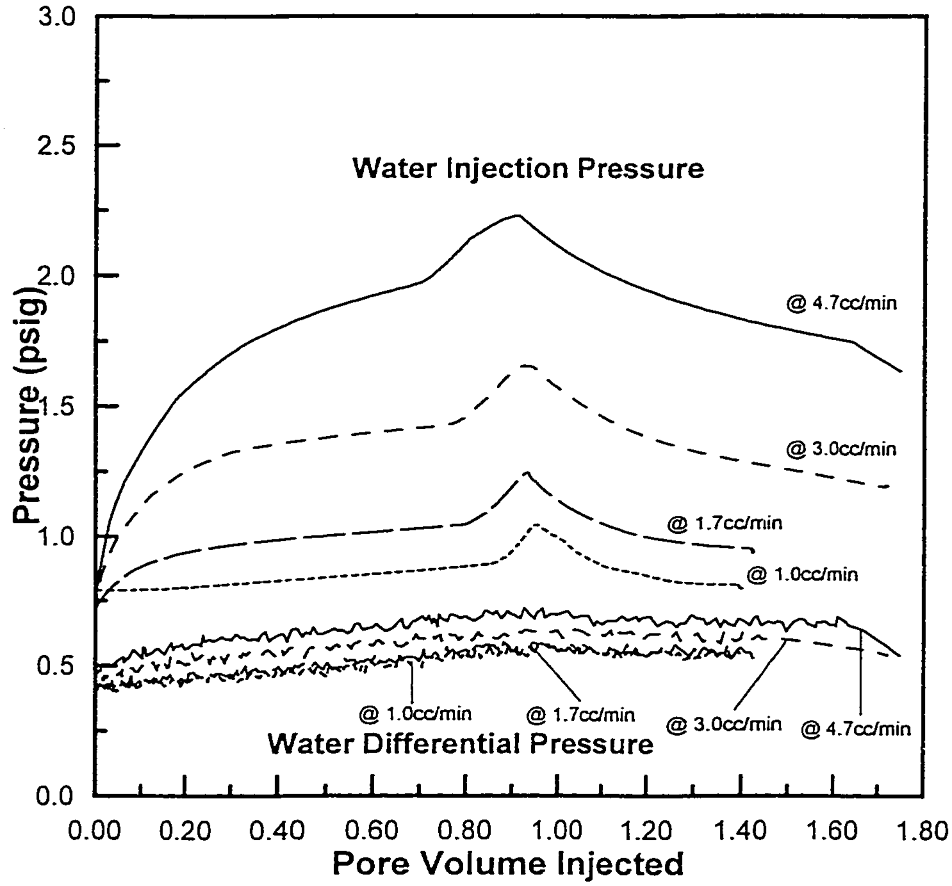

Figure 5.9: Pressure Distributions for BWD from Well # 1

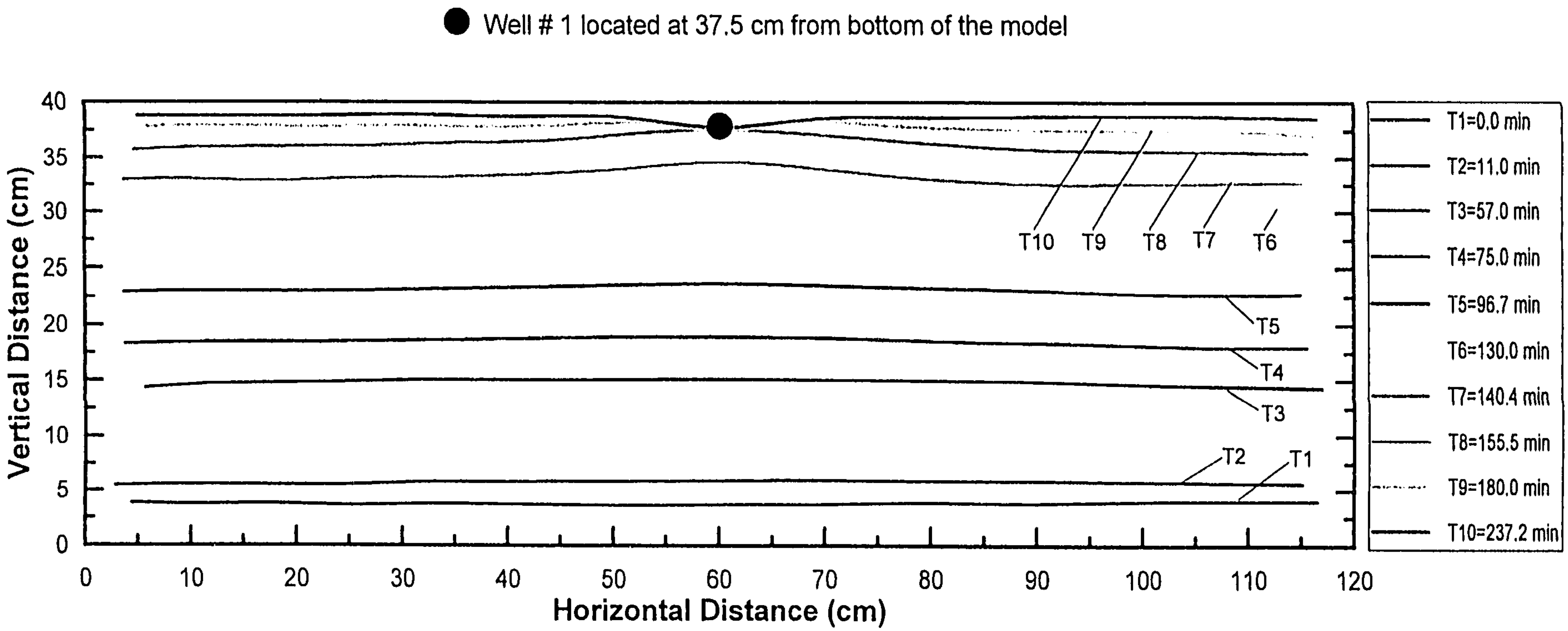

Figure 5.10: Interface movement for BWD at 1.0 cc/min from well # 1

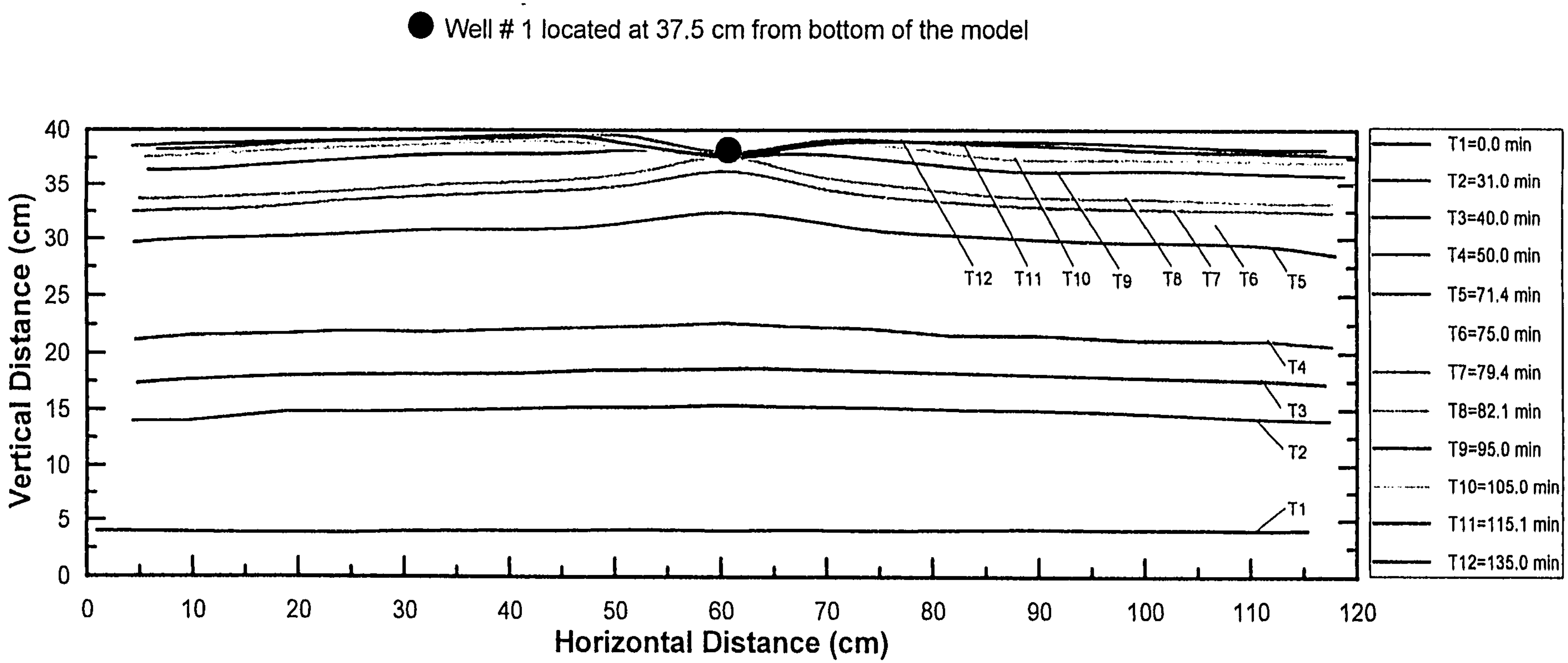

Figure 5.11: Interface movement for BWD at 1.7 cc/min from well # 1

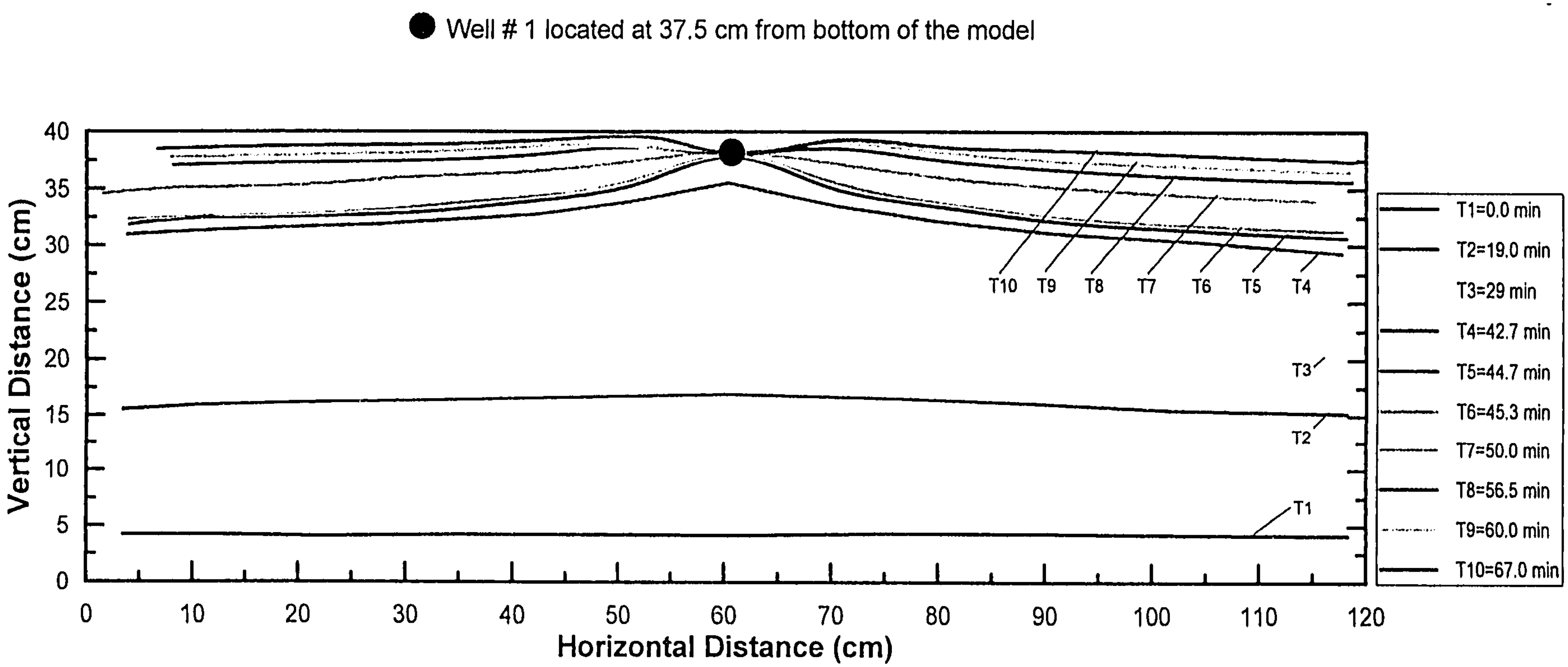

Figure 5.12: Interface movement for BWD at 3.0 cc/min from well # 1

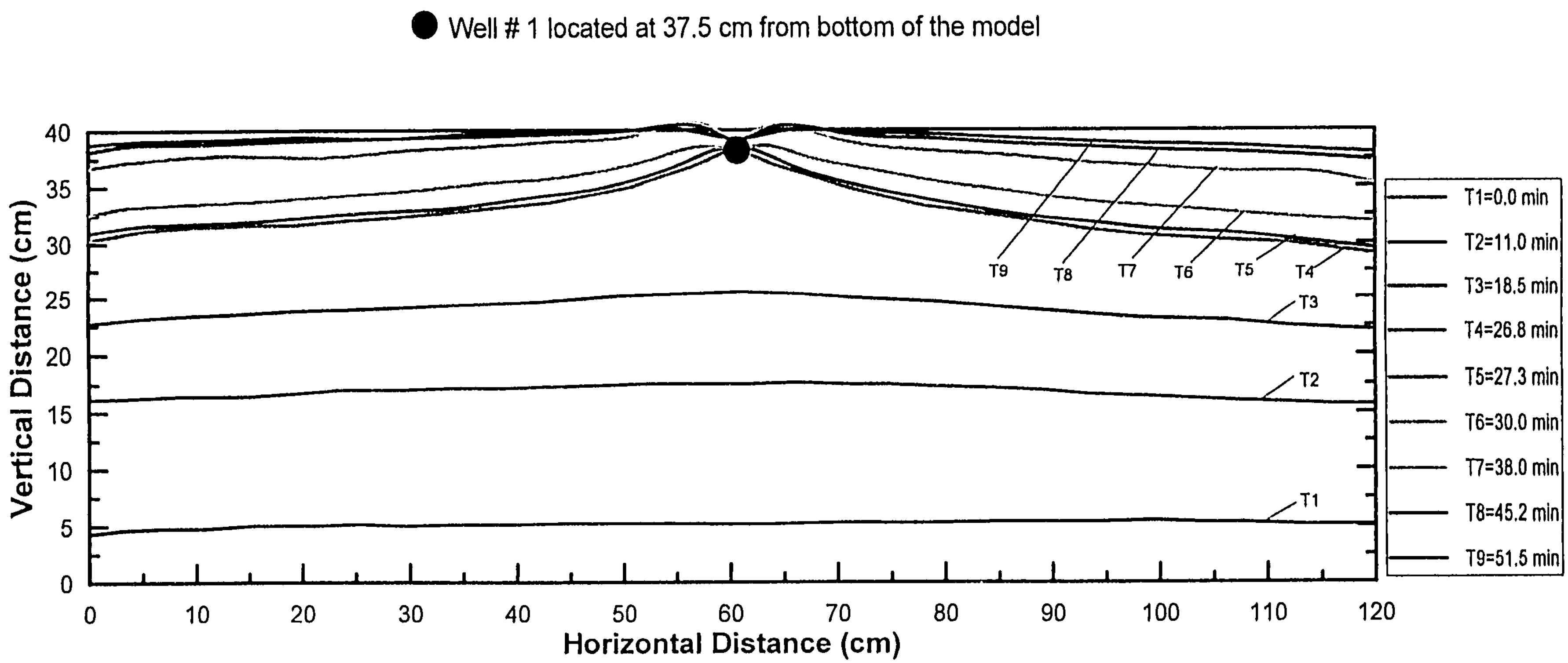

Figure 5.13: Interface movement for BWD at 4.7 cc/min from well # 1

cm from bottom) is located near the top of the model. The oil is displaced upwards by water and produced from the well. In general, as the interface approaches the production well, it becomes curved due to the higher convergent velocities near the well. The three important factors that might affect the stability of the interface are production rates, viscous forces and gravity forces. For upward displacement of the oil by water, the viscous forces tend to make the interface unstable if the viscosity of the water is less than that of oil, while the gravity forces tend to stabilize it if the water has a higher density than oil. Hence, the stability of the interface is governed by any one of these three factors. Since, for the present work viscosity and density differences are fixed and do not change for various experimental runs, therefore the determining factor for the stability of the interface is production rate. The results showed that a stable interface with higher recoveries is obtained for lower production rates. It becomes more curved as the production rate increases giving rise to a prominent cone.

5.2 Gas-Cap Drive Experiments (GCD)

The most suitable location for the well in GCD would be at the bottom of the oil column. As the gas expands from the gas-cap that lies above the oil column in the reservoir, it pushes the oil down. Therefore, if the well is positioned near the bottom of the reservoir, it would be expected to give the maximum recovery because the gas breakthrough in the well is delayed as it takes more time to reach the bottom of the reservoir. Also in doing so the advancing gas front has more oil volume available to be swept away.

Keeping this in mind, the gas-cap drive experiments were conducted with the lowest well location (well # 8) as the production well. Although several experiments were performed, the results of two of these experiments for production rates of 2.6 cc/min and 5.3 cc/min are presented here. These results are shown in figures 5.14 and 5.15 for 2.6 cc/min and 5.3 cc/min cases, respectively.

5.2.1 Oil Recovery

Figure 5.16 shows the comparison of the oil recovery for the two production rates as a function of time. It is important to mention here that the experiments were terminated soon after gas breakthrough since the oil recovery was insignificant after that.

The results show that the oil recovery is higher for higher production rate. Also the curve for the higher production rate is steeper, which means that more oil is being recovered per unit time. The oil recovered at breakthrough for 5.3 cc/min and 2.6 cc/min is 87.8% and 83.5%, respectively.

These results indicate that the effective application of the gas-cap drive means producing at higher rates. However, the velocity of the gas should be controlled in such a manner that it does not become so high that the gas

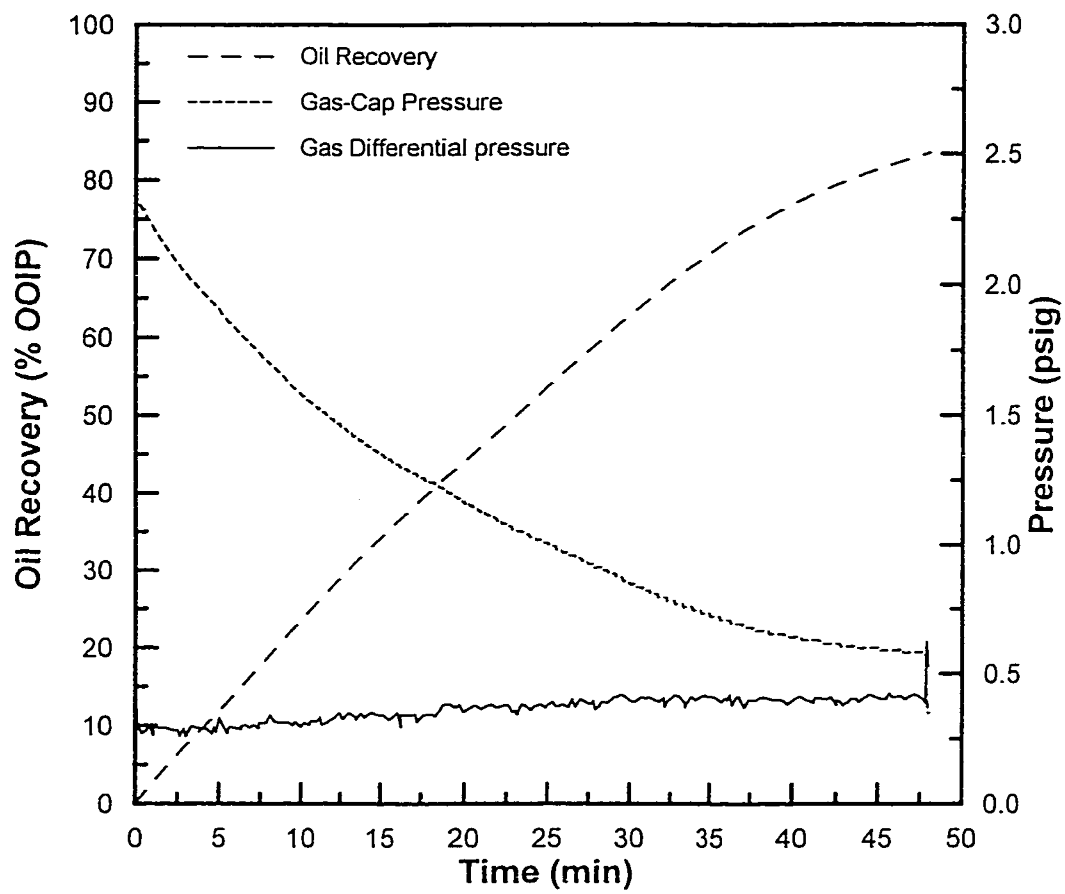

Figure 5.14: Production performance for GCD @ 2.6 cc/min from well # 8

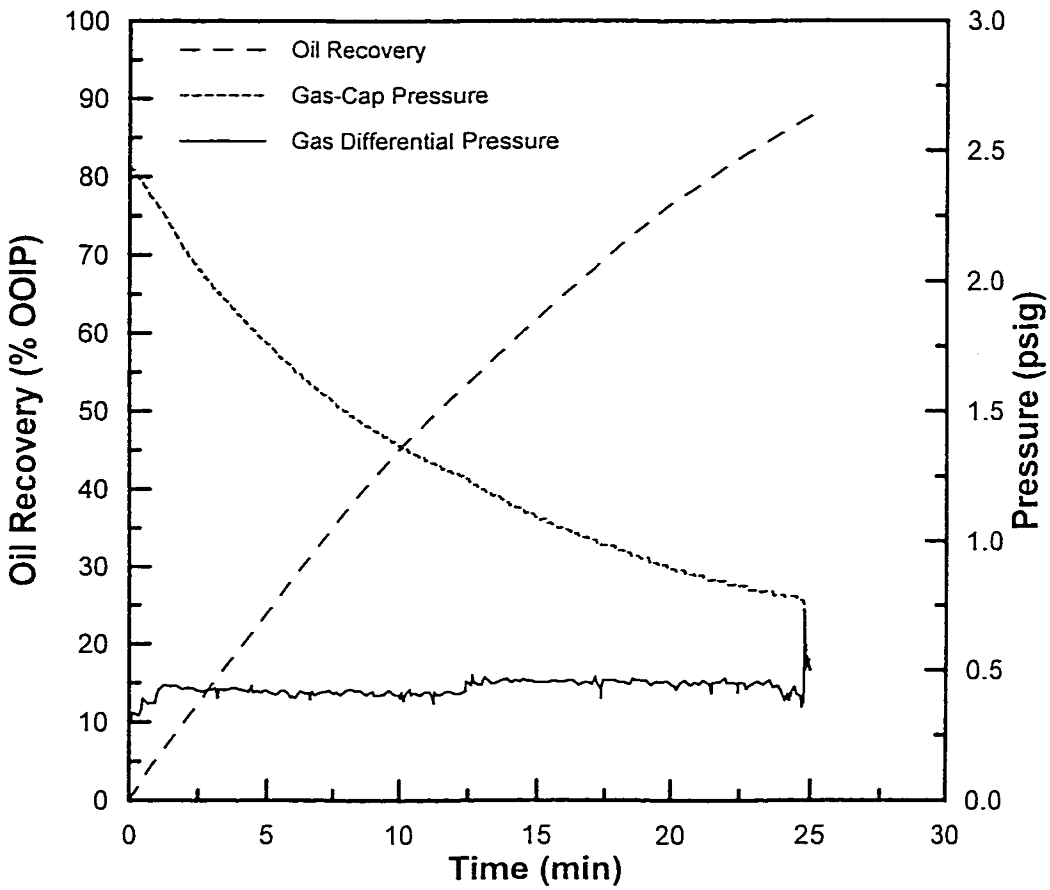

Figure 5.15: Production performance for GCD @ 5.3 cc/min from well # 8

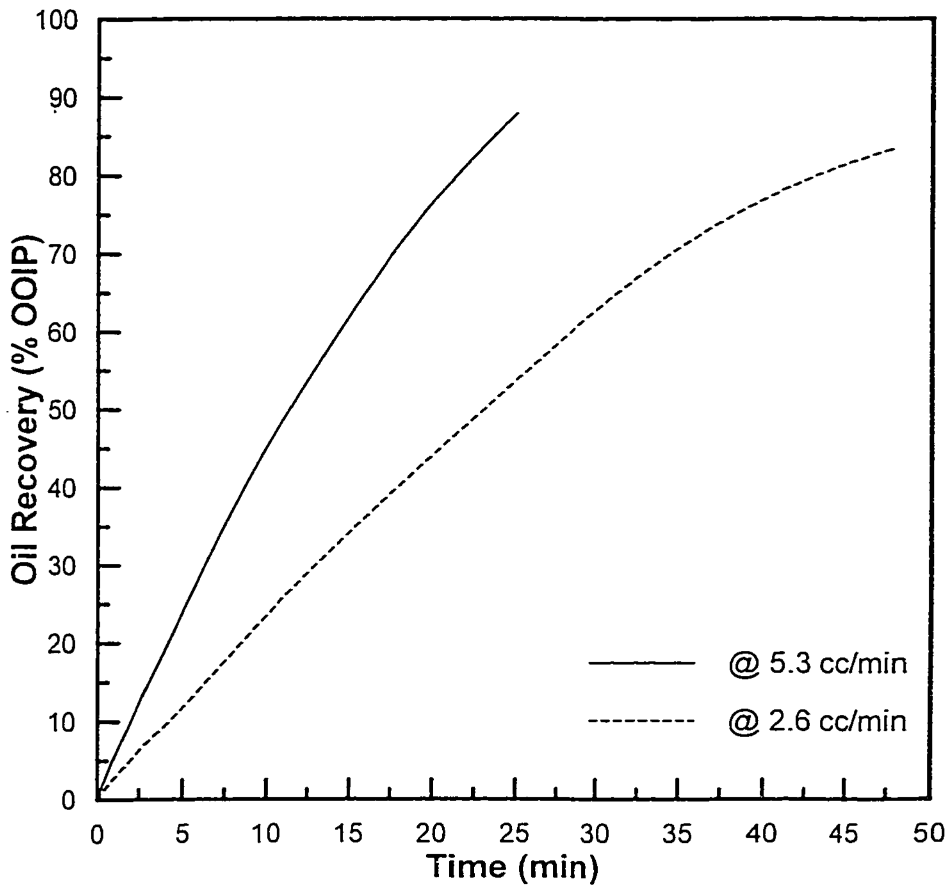

Figure 5.16: Oil Recovery Comparison for GCD from Well # 8

fingers through the oil and bypass it, but rather displaces it smoothly. It is expected that the interface stability will be disturbed at very high rates, giving rise to a single or multiple gas fingers through the oil.

5.2.2 Breakthrough Time

It is observed that breakthrough time will be lower for higher production rates. From Table 5-2, the respective breakthrough times for the 5.3 cc/min and 2.6 cc/min runs are 25 and 48 minutes.

5.2.3 Pressure Distribution

The gas-cap pressure and the gas differential pressure versus time are shown in figure 5.17 for the two production rates studied. It is seen that the inlet pressure starts at around 2.5 psig and then drops continuously until breakthrough whereas the differential pressure almost remains constant with a slightly increasing trend. It is important to note that for GCD, the gas-cap pressure is actually depleting itself. Thus as production starts, the gas pressure declines continuously. It is also observed (figure 5.17) that the inlet pressure shows a greater decline at the higher production rate.

5.2.4 Interface Movement

The results for the interface movement for the GCD are shown in figures 5.18 and 5.19. The interface approaches the production well (well # 8

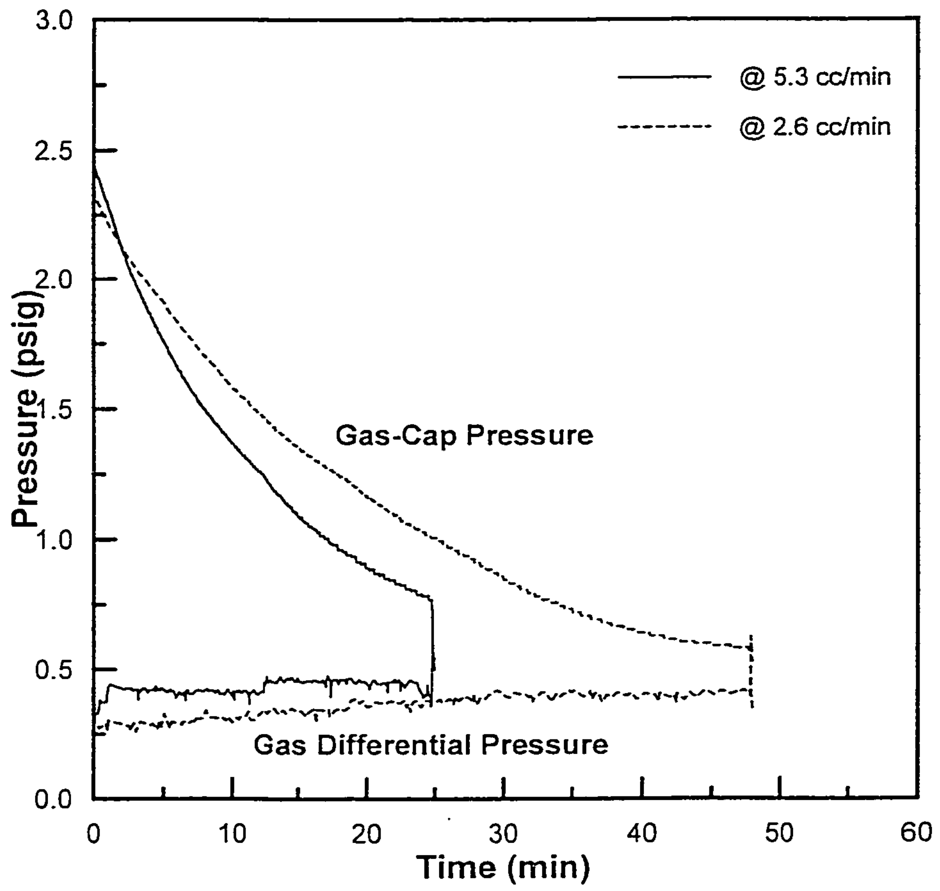

Figure 5.17: Pressure Distributions for GCD from Well # 8

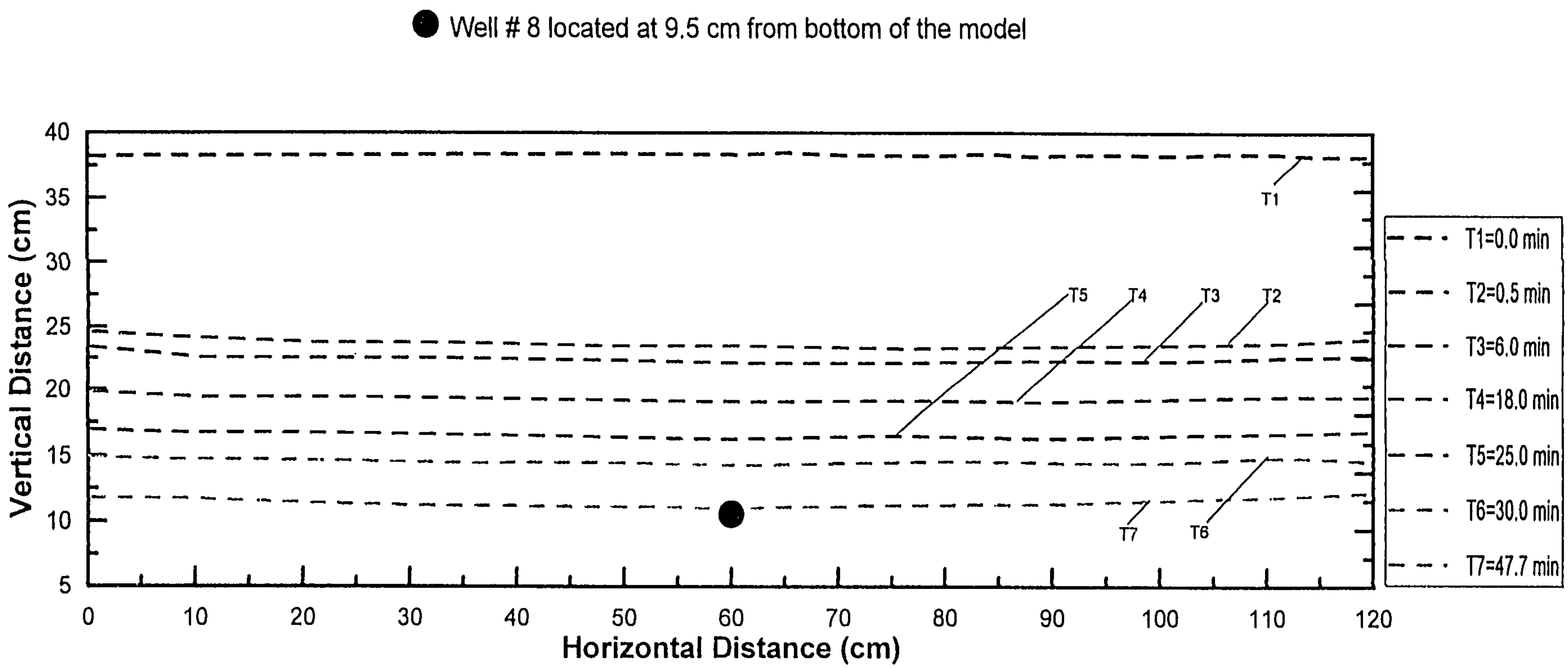

Figure 5.18: Interface movement for GCD at 2.6 cc/min from well # 8

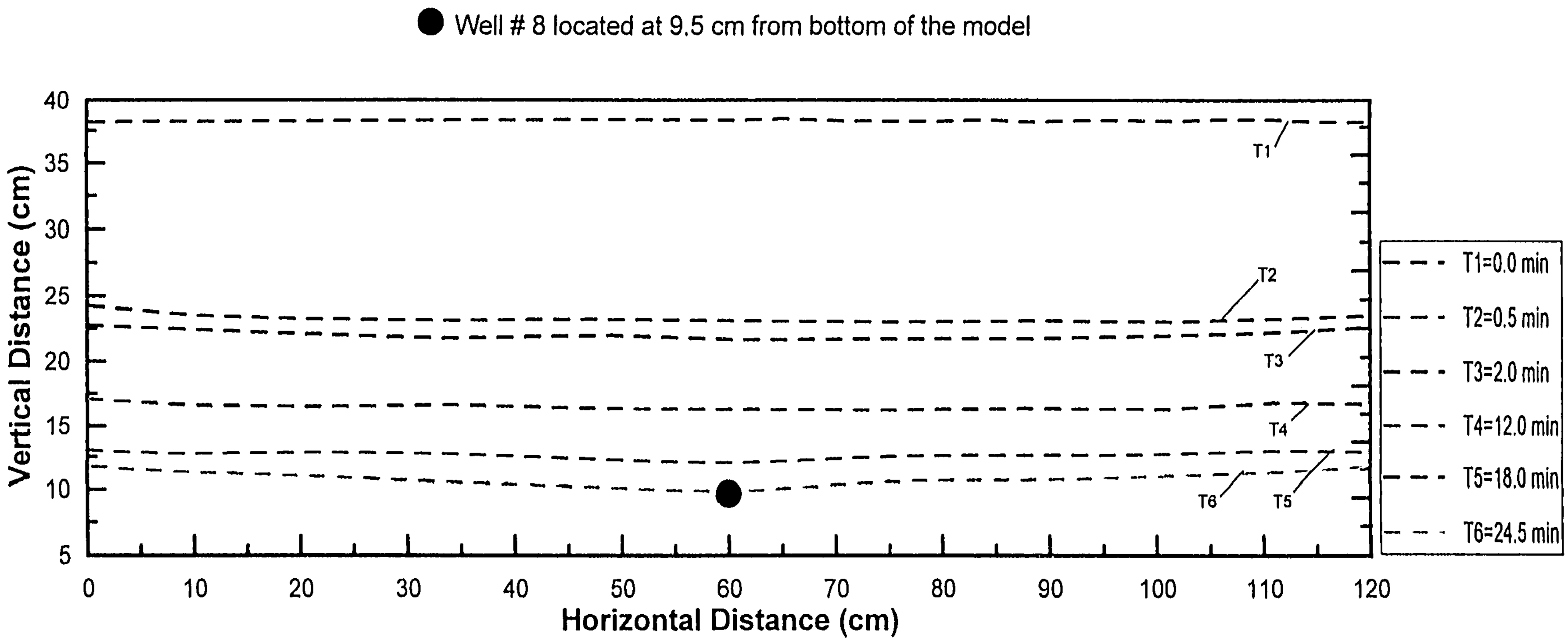

Figure 5.19: Interface movement for GCD at 5.3 cc/min from well # 8

at 9.5 cm from bottom of the model) more quickly at the higher production rate. Initially it is almost a horizontal plane but as it moves downwards it becomes slightly curved. It is expected that a cone will appear at the interface as the production rate is further increased. For the present study, higher rates than 5.3 cc/min could not be achieved because of equipment restrictions and low initial gas pressure. Therefore, the critical rate could not be determined. But, from the general trend of the results it is clear that it is better to produce just below the critical rate to get a higher recovery. If the production rate is made higher than the critical rate, instant coning of gas is expected to occur with gas breaking through very quickly.

5.3 Simultaneous Bottom-Water and Gas-Cap Drive (SWGD)

From the experiments conducted for BWD and GCD it is concluded that if both of them are applied together then the best well location would be somewhere in the middle region of the model. For SWGD, the well locations at the top and the bottom should be avoided because they will cause an early breakthrough of gas or water. Therefore, experiments were conducted using wells in the middle portion of the model for SWGD in order to find out the optimum well location. The results of twelve of these runs that were carried out for well numbers 6,7 and 8 are presented here (figures 5.20 to 5.31).

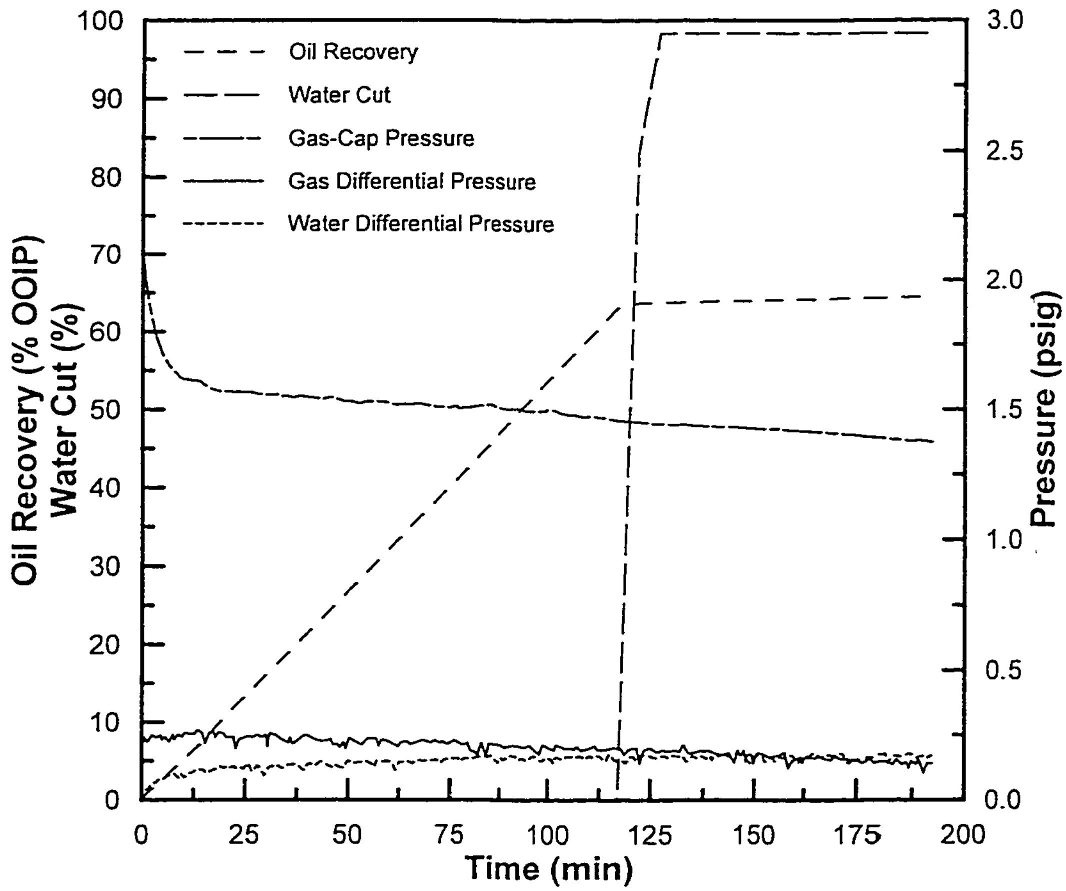

Figure 5.20: Production performance for SWGD at 1cc/min from Well # 6

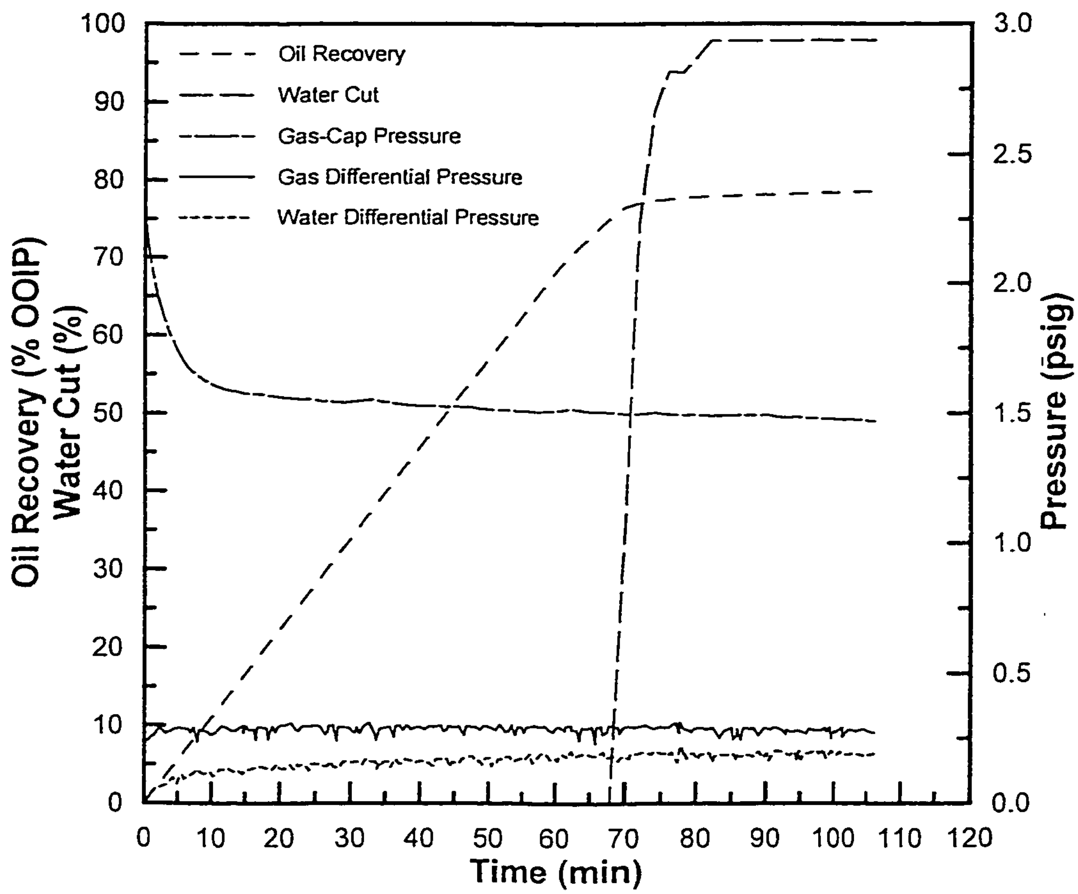

Figure 5.21: Production performance for SWGD at 2cc/min from Well # 6

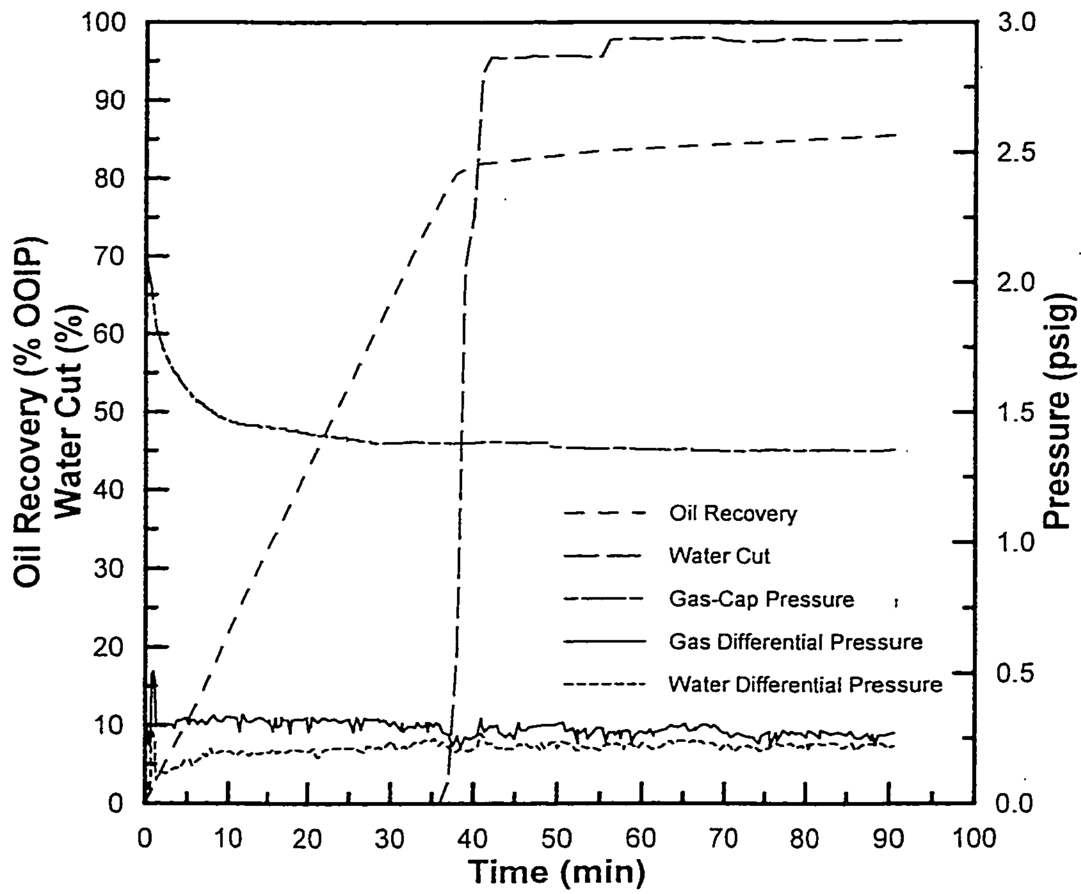

Figure 5.22: Production performance for SWGD at 4cc/min from Well # 6

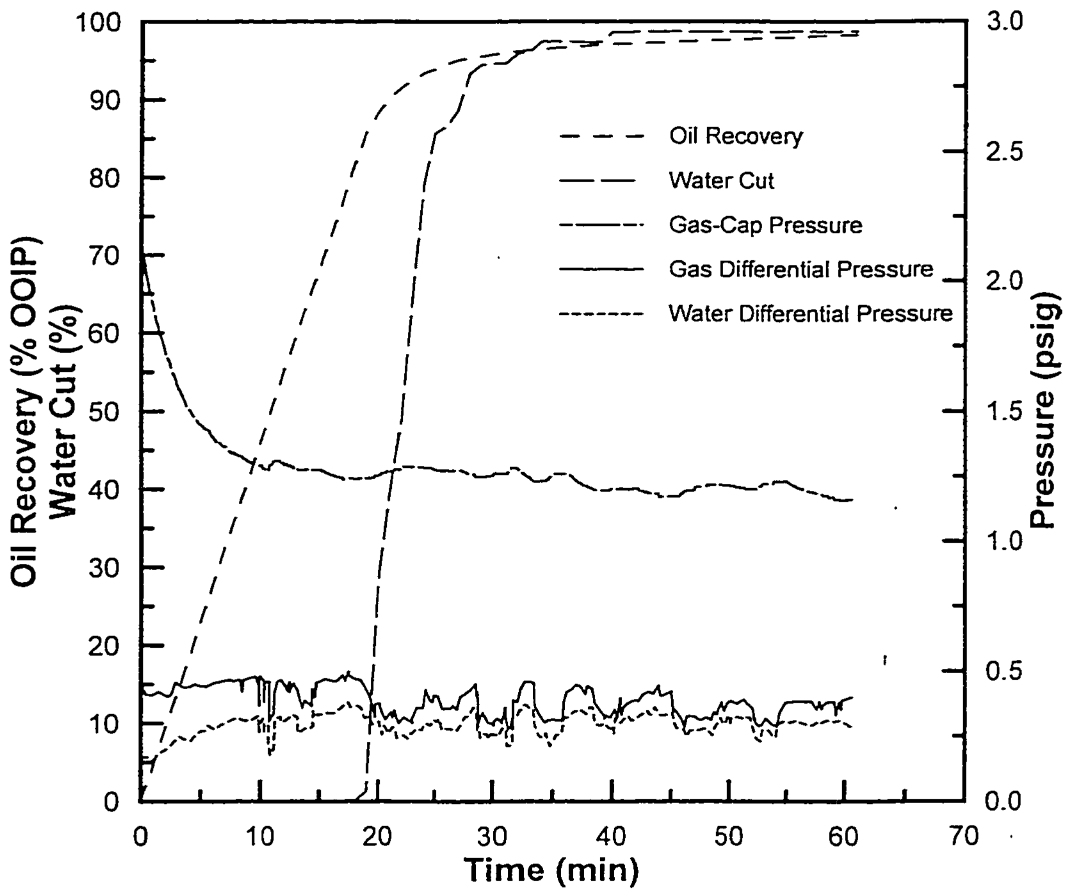

Figure 5.23: Production performance for SWGD at 7.6cc/min from Well # 6

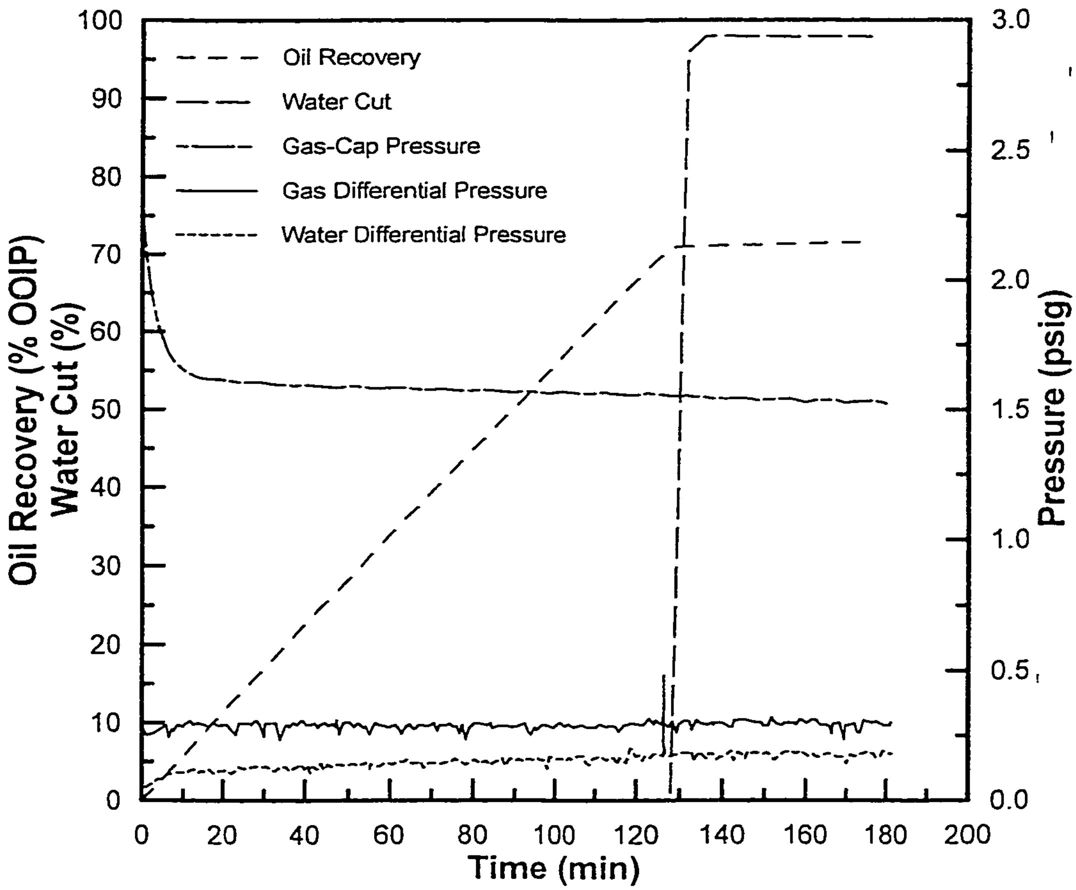

Figure 5.24: Production performance for SWGD at 1cc/min from Well # 7

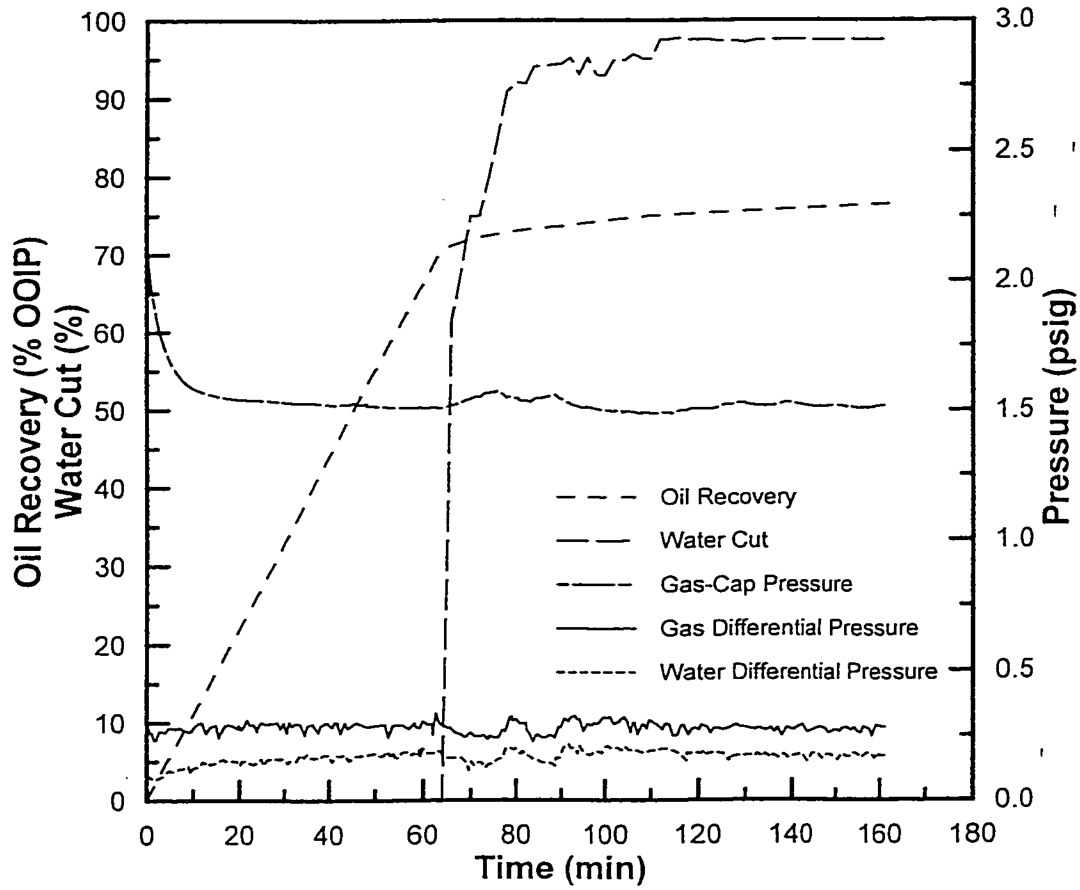

Figure 5.25: Production performance for SWGD at 2cc/min from Well # 7

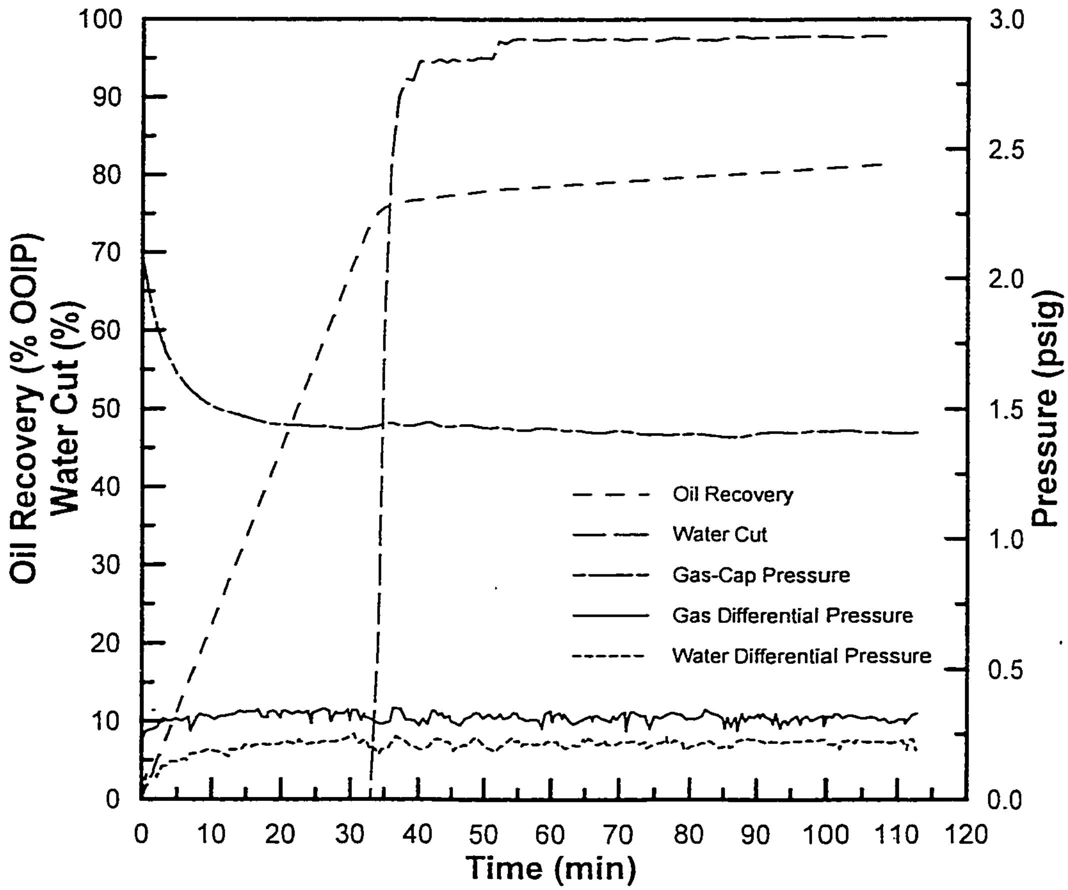

Figure 5.26: Production performance for SWGD at 4cc/min from Well # 7

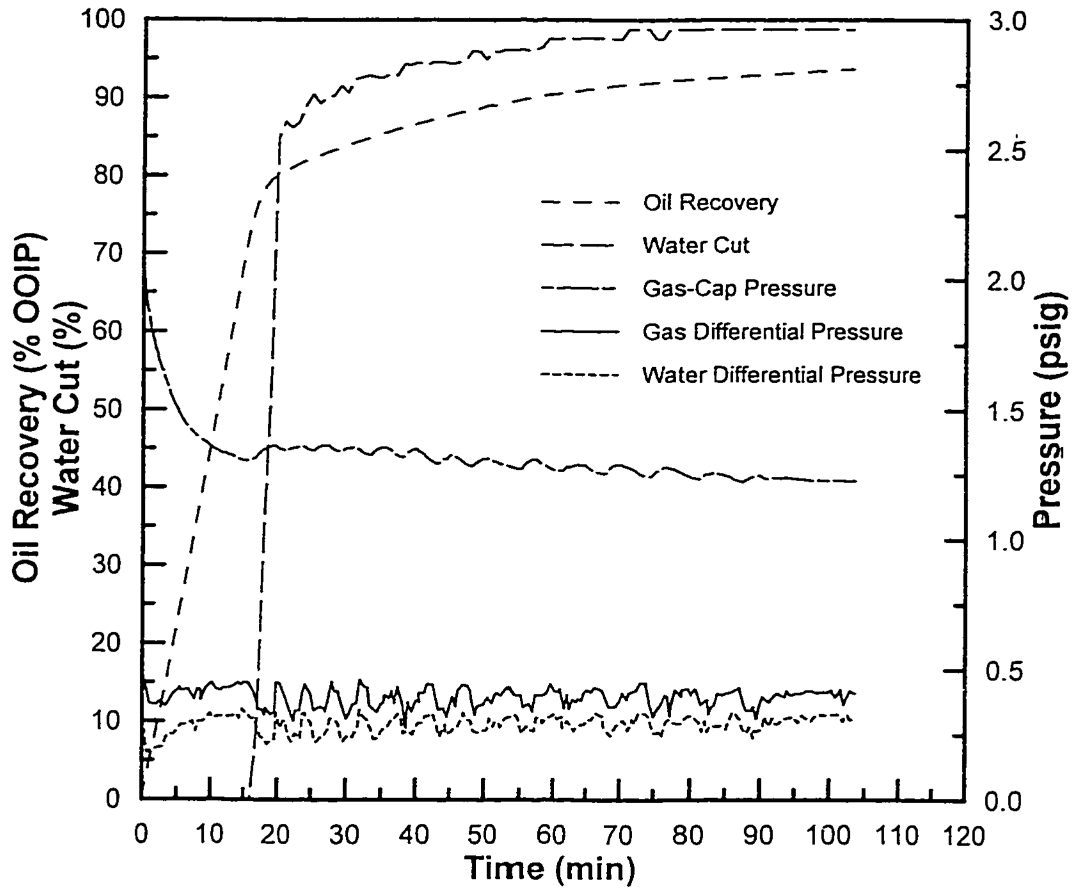

Figure 5.27: Production performance for SWGD at 7.6cc/min from Well # 7

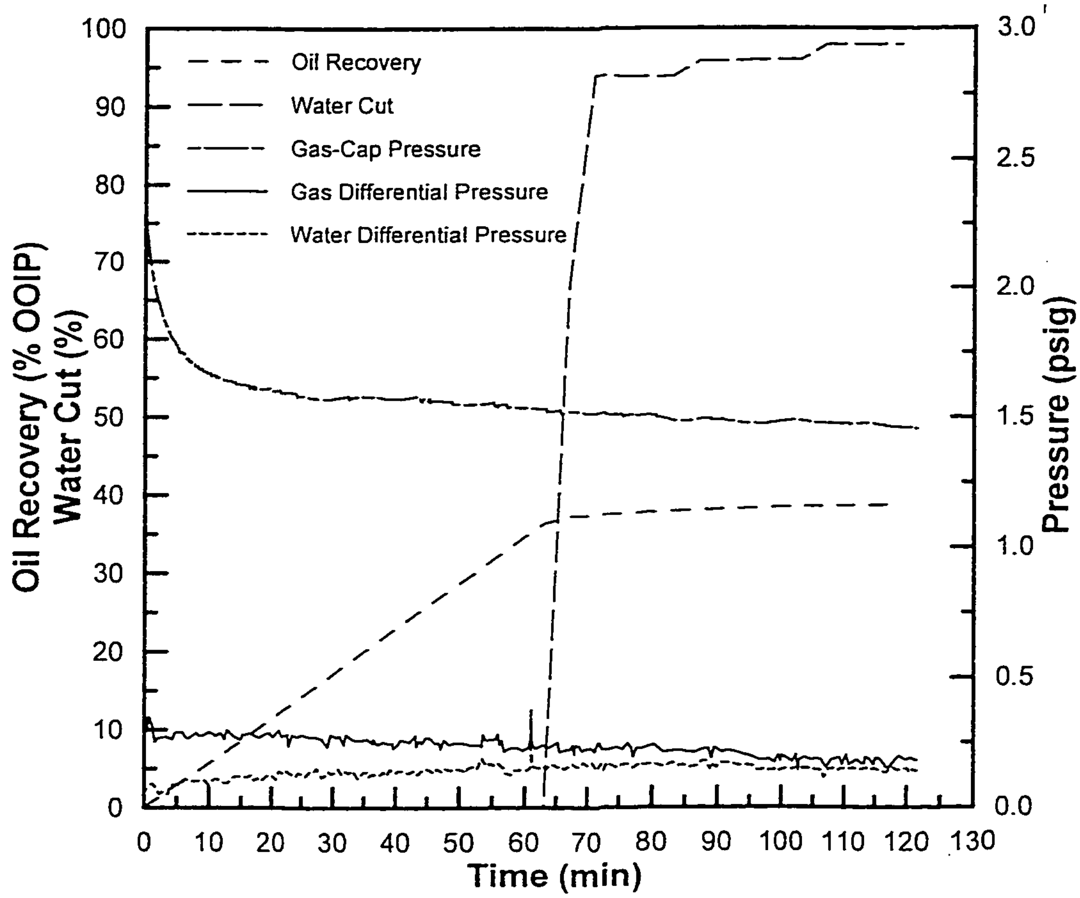

Figure 5.28: Production performance for SWGD at 1cc/min from Well # 8

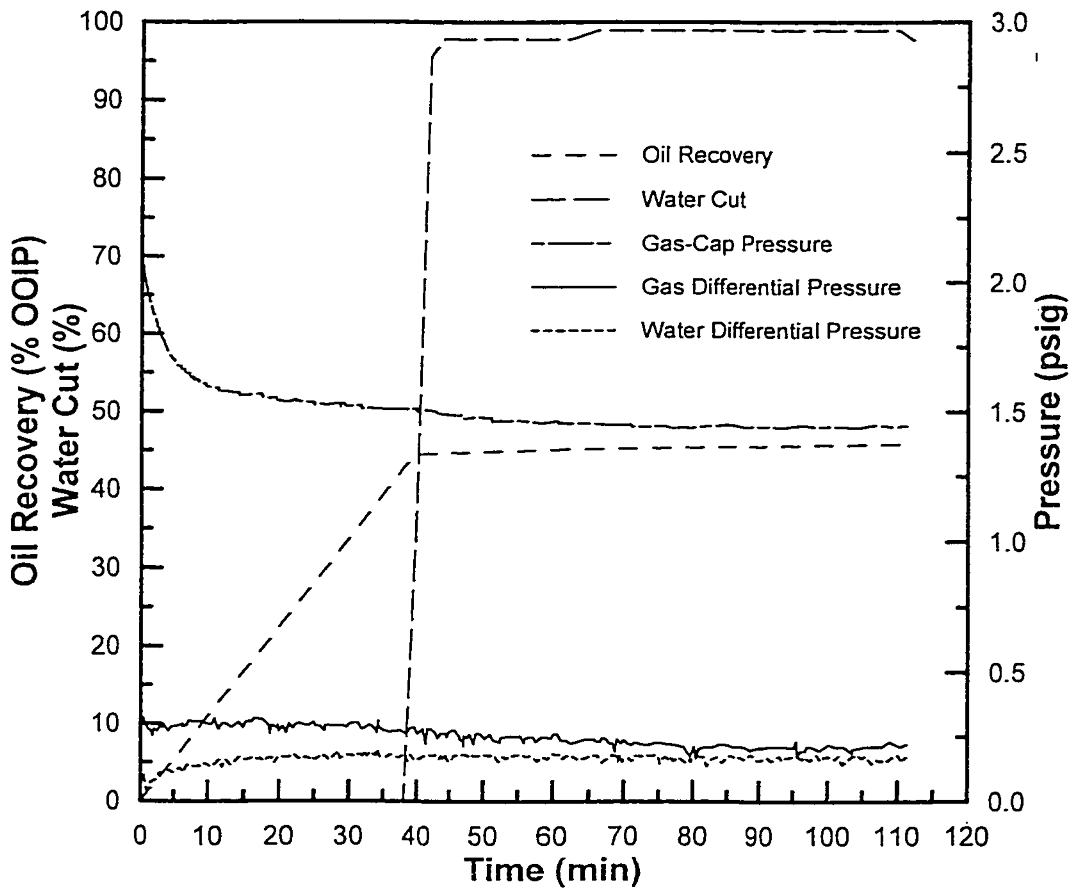

Figure 5.29: Production performance for SWGD at 2cc/min from Well # 8

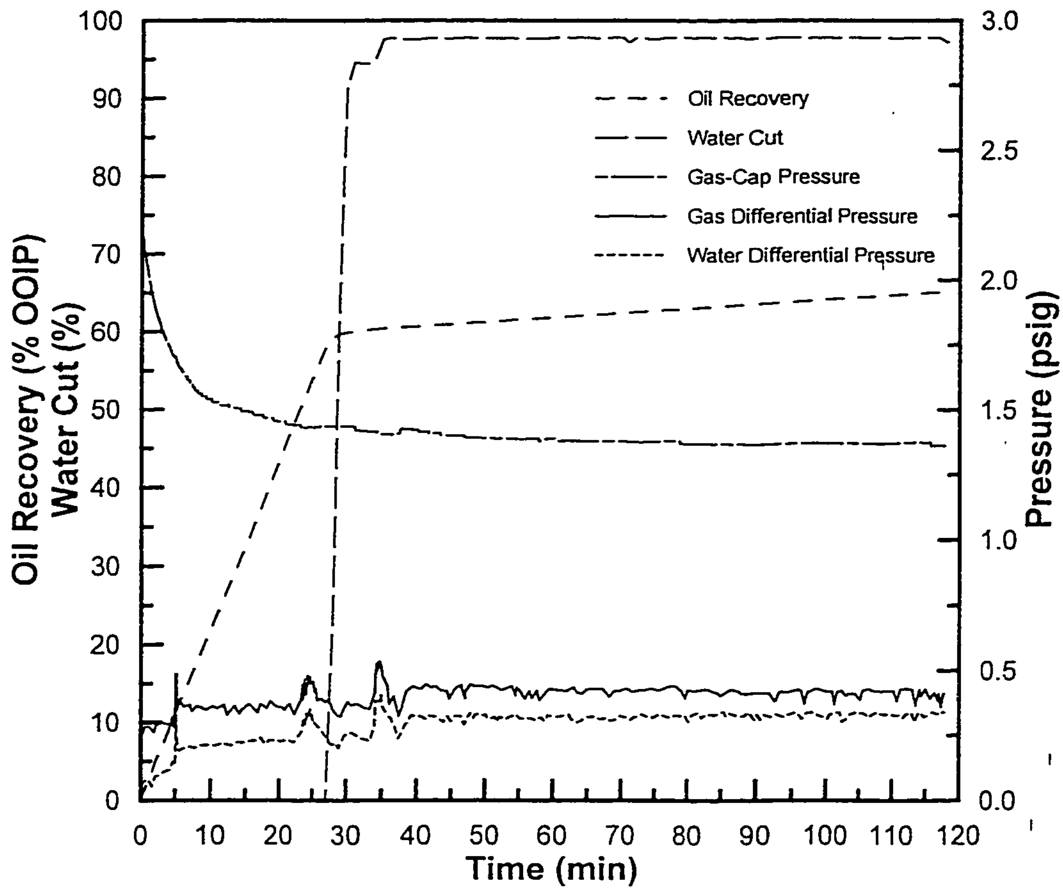

Figure 5.30: Production performance for SWGD at 4cc/min from Well # 8

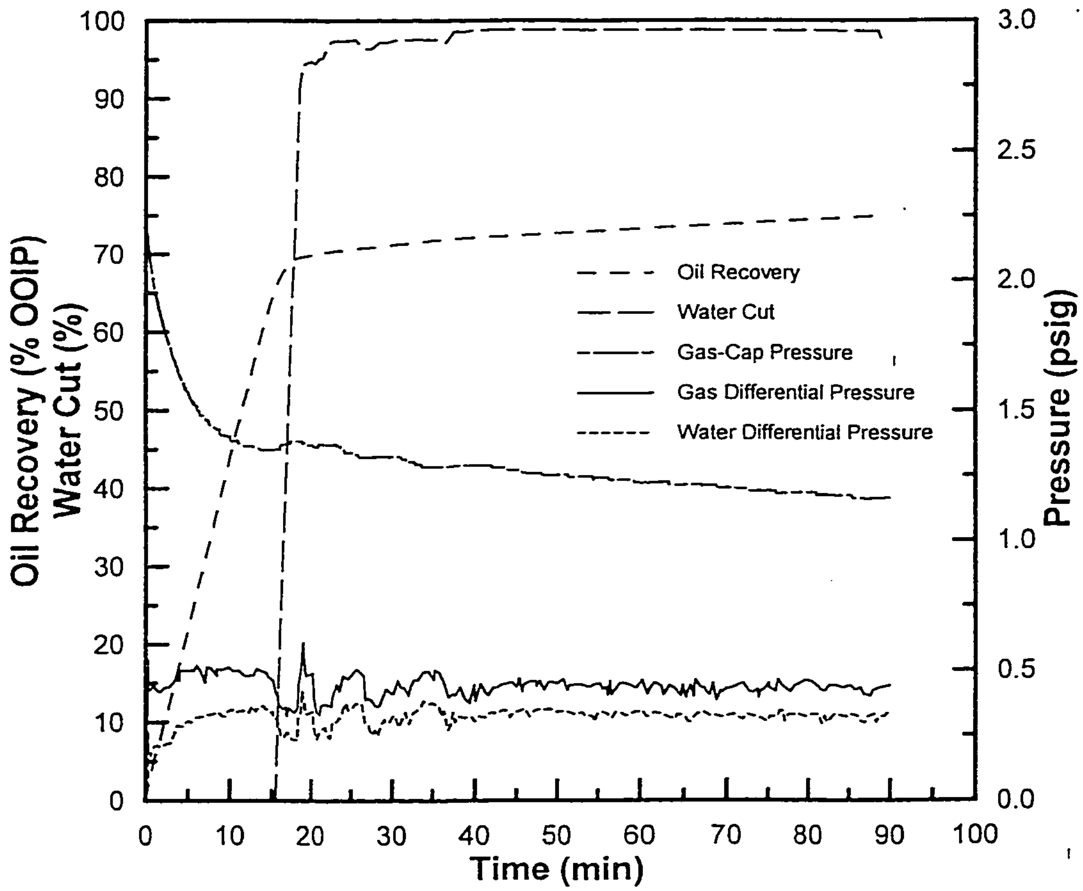

Figure 5.31: Production performance for SWGD at 7.6cc/min from Well # 8

For wells above well # 6, that are wells number 1 to 5, the gas/oil interface moves too fast and breakthrough occurs very quickly without giving any significant oil recovery. Similarly for well # 9 below 8, the oil/water interface breaks through very early and is therefore not discussed here. For each of the three well locations (No. 6, 7 & 8), experiments were conducted at four different production rates for each of the three well locations (refer to Table 5-2). Average production rates of 1, 2, 4, 7.6 cc/min were used. But, as the production rates were being controlled by flow controllers that were being handled manually, all the rates were not exactly the same for different well locations but were all within a range of 10 % error.

5.3.1 Oil Recovery

Figures 5.32 to 5.34 illustrate the effect of production rate on the oil recovery for the three well locations. It is observed from these figures that for the same well location the oil recovery is higher for higher production rates provided that there is no significant gas/oil or water/oil interface disturbance. For example at well # 6 (figure 5.32) the maximum recovery at breakthrough achieved for a production rate of 7.6 cc/min is 81.7% as compared to 63.7% at 1 cc/min. Another important observation from these figures is that for higher production rates the slope of the oil recovery curve is also higher, that is more oil per unit time is being recovered at higher production rates.

Therefore, the effective application of the gas-cap and the bottom-water at the same time requires not only controlling the advance of the gas

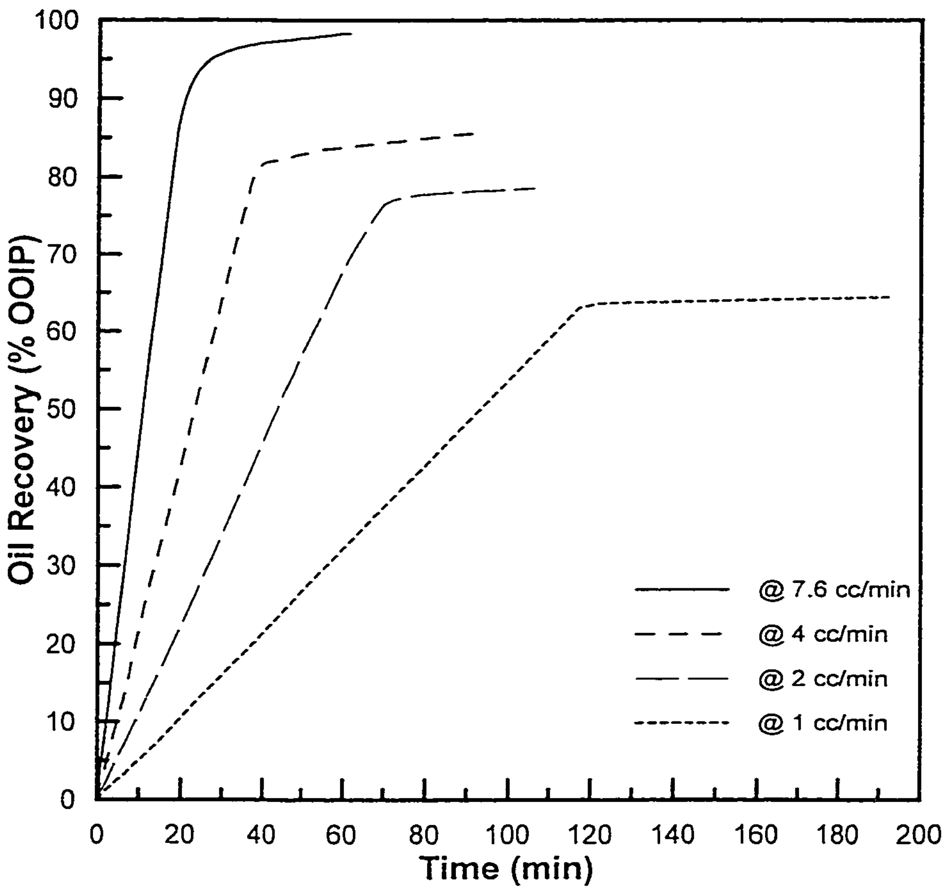

Figure 5.32: Comparison of Oil Recovery for Well # 6 at different production rates for SWGD

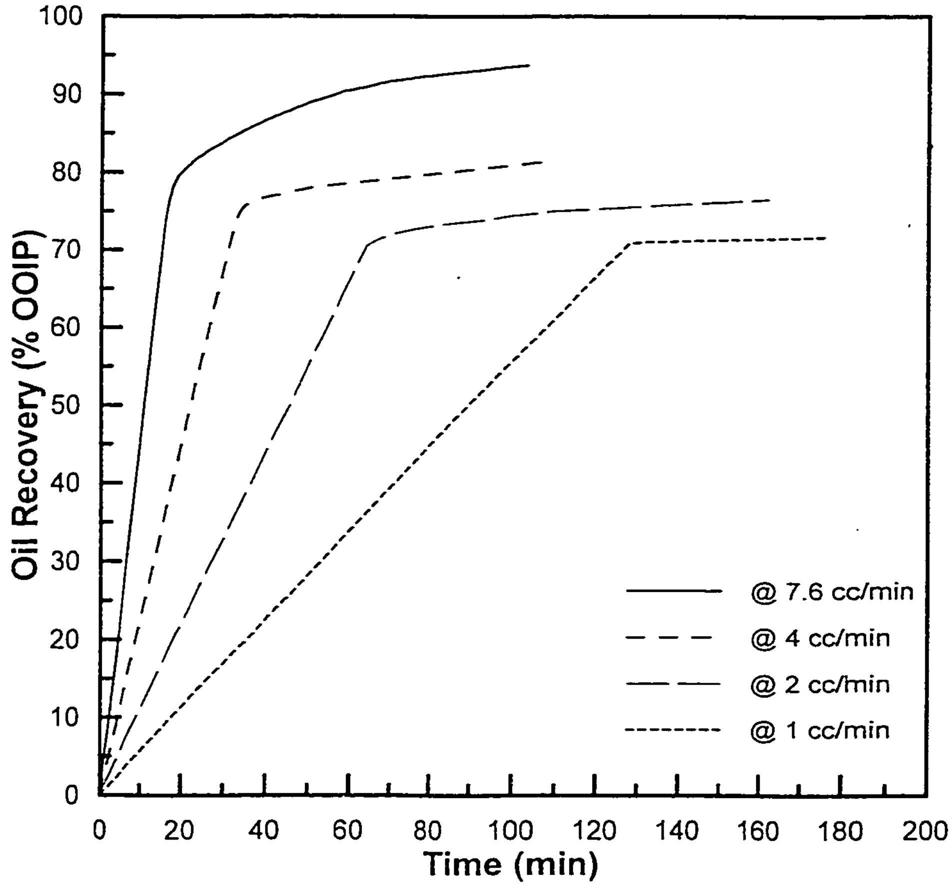

Figure 5.33: Comparison of Oil Recovery for Well # 7 at different production rates for SWGD

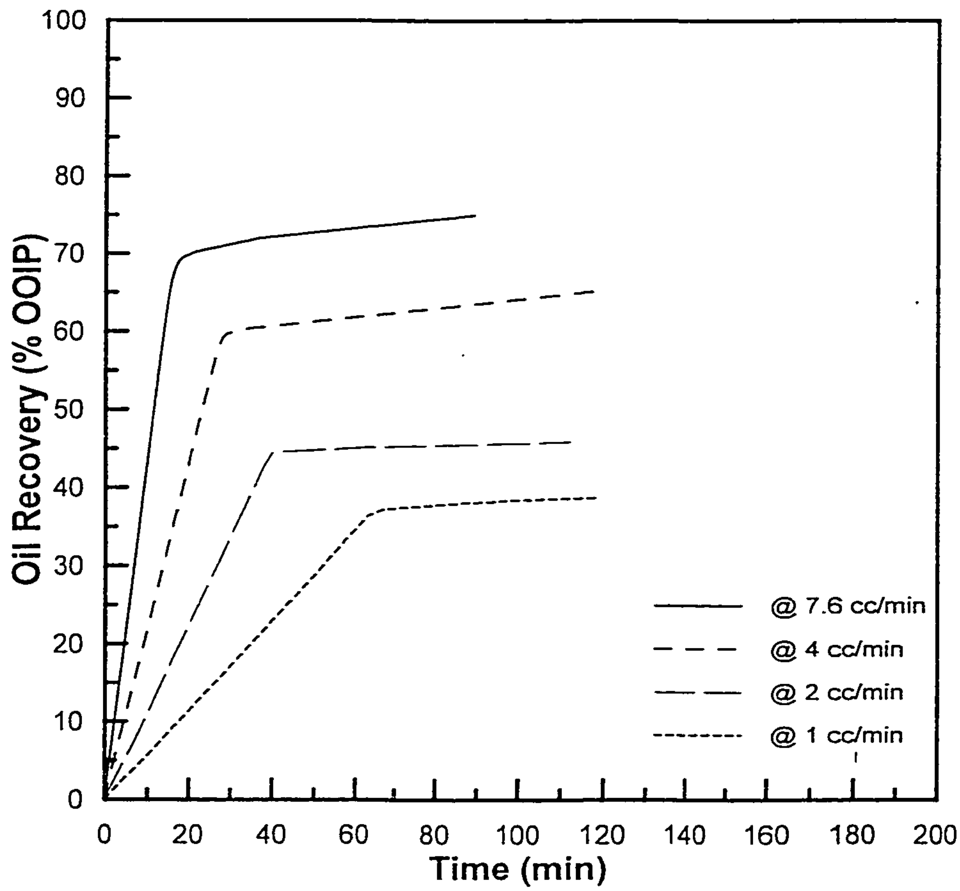

Figure 5.34: Comparison of Oil Recovery for Well # 8 at different production rates for SWGD

flow in such a manner that it does not finger through the oil and bypass it but also to utilize the energy of the strong bottom-water to get the maximum recovery. This is achieved at a production rate that is high enough to provide a high gas velocity which can displace most of the oil behind the gas/oil interface without actually destabilizing it and at the same time let the approaching water front to give a good sweep of the oil in front of it. At too high rate, the interface stability will be disturbed giving rise to a single or multiple gas or water fingers through the oil instead of pushing it in front of it and displacing it efficiently.

Figures 5.35 to 5.38 present the same results in another form to illustrate the effect of well location on oil recovery for the different production rates studied. These figures show that at higher rates, recovery follows the same trend, being highest for well # 6, then for 7 and then for 8. The recovery decreases as the well gets closer to the water/oil interface. But at 1cc/min, the oil recovery for well # 7 is more than that of well # 6 (figure 5.35). This is probably because of the fact that at higher rates oil is being recovered at a faster rate and the approach of both the interfaces (i.e. gas/oil and water/oil) is in such a manner that it maximizes the recovery for well # 6. But at 1cc/min the time to breakthrough is significantly increased due to the low rate that slows down the approaching interfaces. This causes the gas to breakthrough momentarily in well # 6, which is at a higher location than well # 7, and thus the gas cap pressure is no longer high enough to provide the

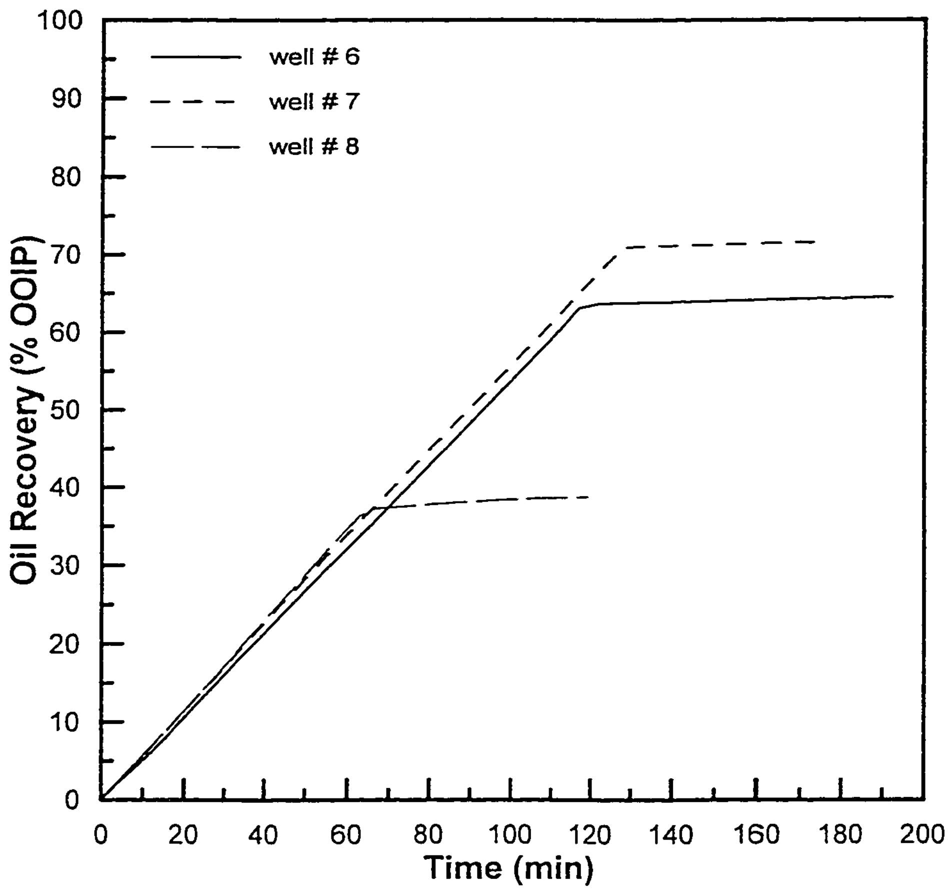

Figure 5.35: Comparison of Oil Recovery at 1cc/min from different wells for SWGD

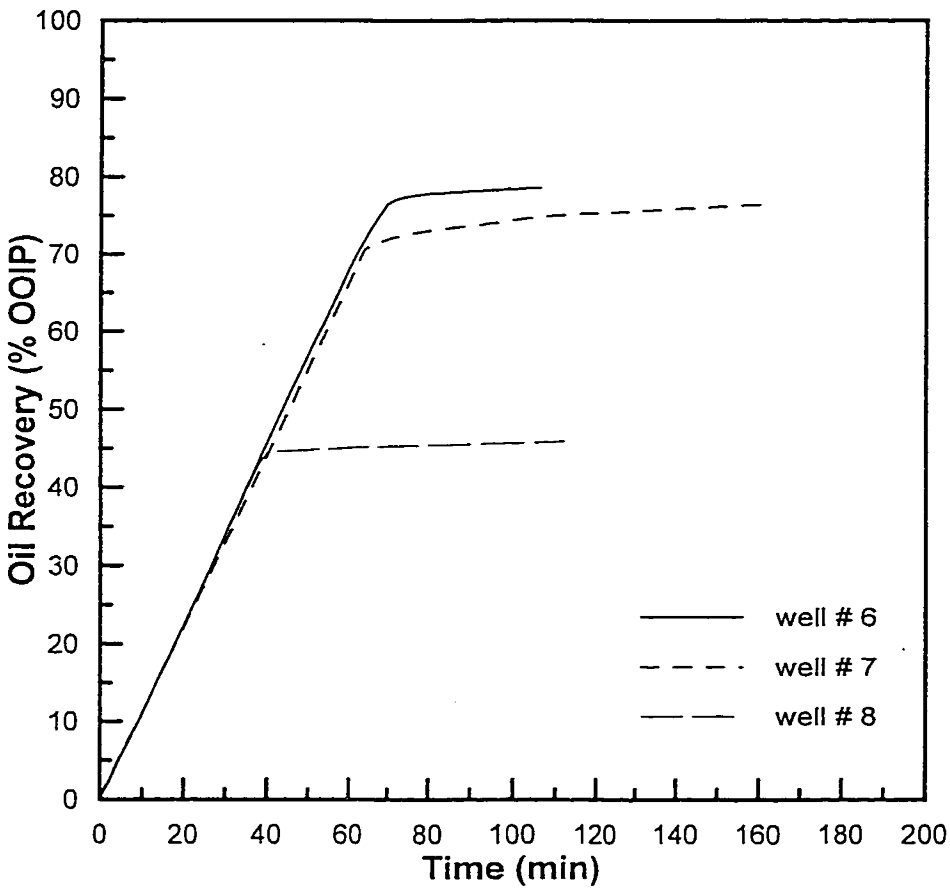

Figure 5.36: Comparison of Oil Recovery at 2cc/min from different wells for SWGD

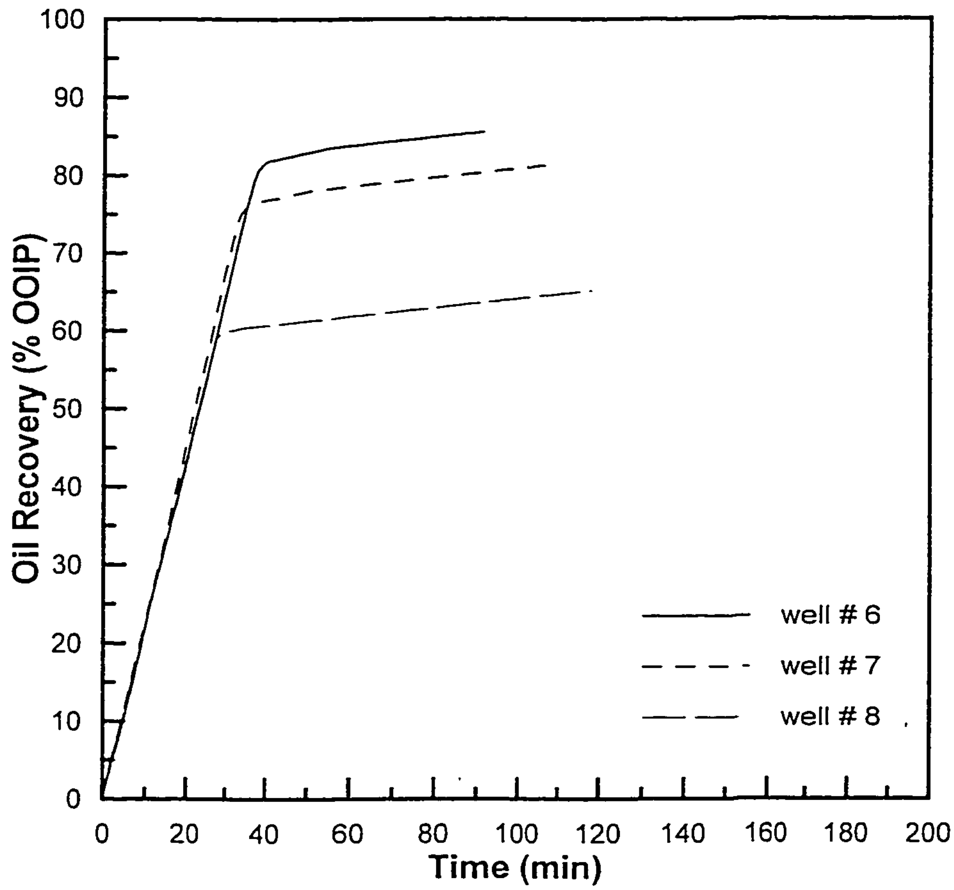

Figure 5.37: Comparison of Oil Recovery at 4cc/min from different wells for SWGD

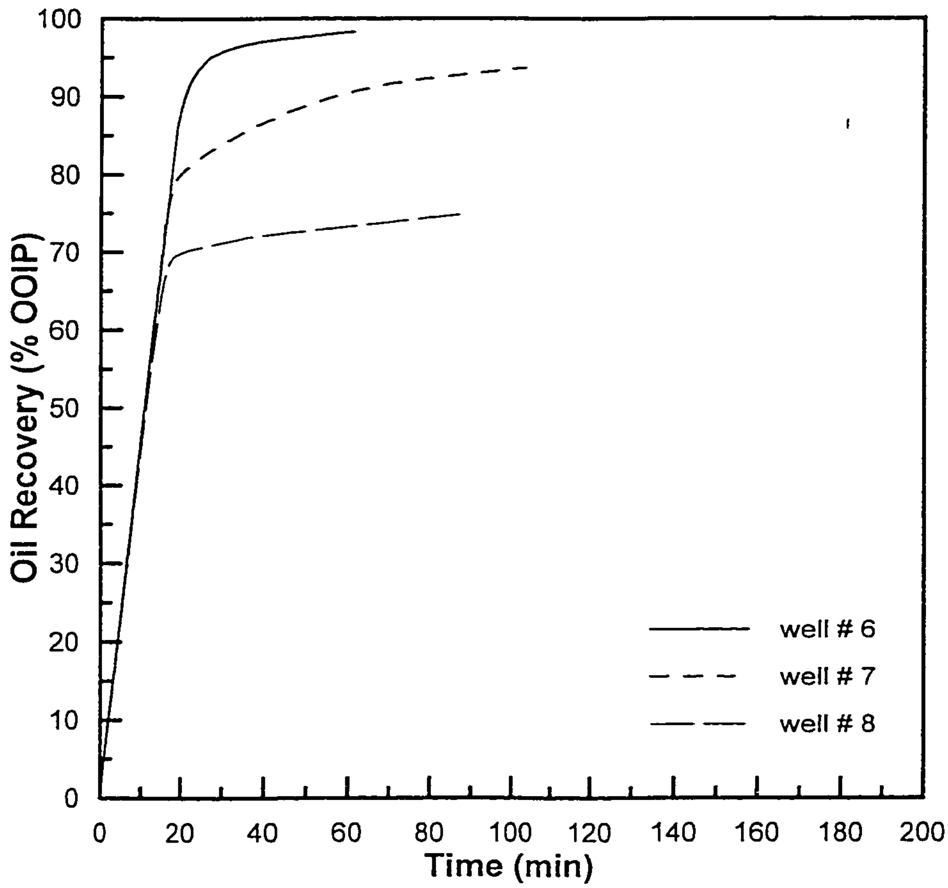

Figure 5.38: Comparison of Oil Recovery at 7.6cc/min from different wells for SWGD

balanced support to the incoming water-front for a higher oil recovery. But for well # 7, lying between 6 and 8, this does not happen thus the balanced support of the two drives is available to it a few minutes longer and thus it is able to give slightly higher recovery.

Figure 5.39 shows the relationship between oil recovery at breakthrough and the production rate for different well locations. It can be seen from this figure that there is a clear increasing trend at higher rates.

5.3.2 Breakthrough Time

Breakthrough time decreases with production rate for all well locations (Table 5-2). For example, for well # 6 breakthrough occurs at 118 minutes at 1cc/min while it occurs at 18 minutes at 7.6cc/min. Well # 6 has a longer time to breakthrough than that for well # 7 and well # 8 for all the production rates except at 1cc/min. Well # 8 has the lowest breakthrough time because it is closer to the water/oil interface and therefore water breaks through very early. Well # 6 is the farthest from the water/oil interface but closest to the gas/oil interface, so it is more prone to gas breaking through in first. But at higher rates the gas pressure depletes faster and quickly looses the force to push the oil column down at the same intensity. Also, because of this lowered gas pressure, the water finds more room to push the oil up at a faster pace. Thus the gas/oil interface does not really advance further after this and just provides a constant pressure boundary against which the water pushes the oil into the well. Thus more oil is recovered for well # 6 and water breakthrough

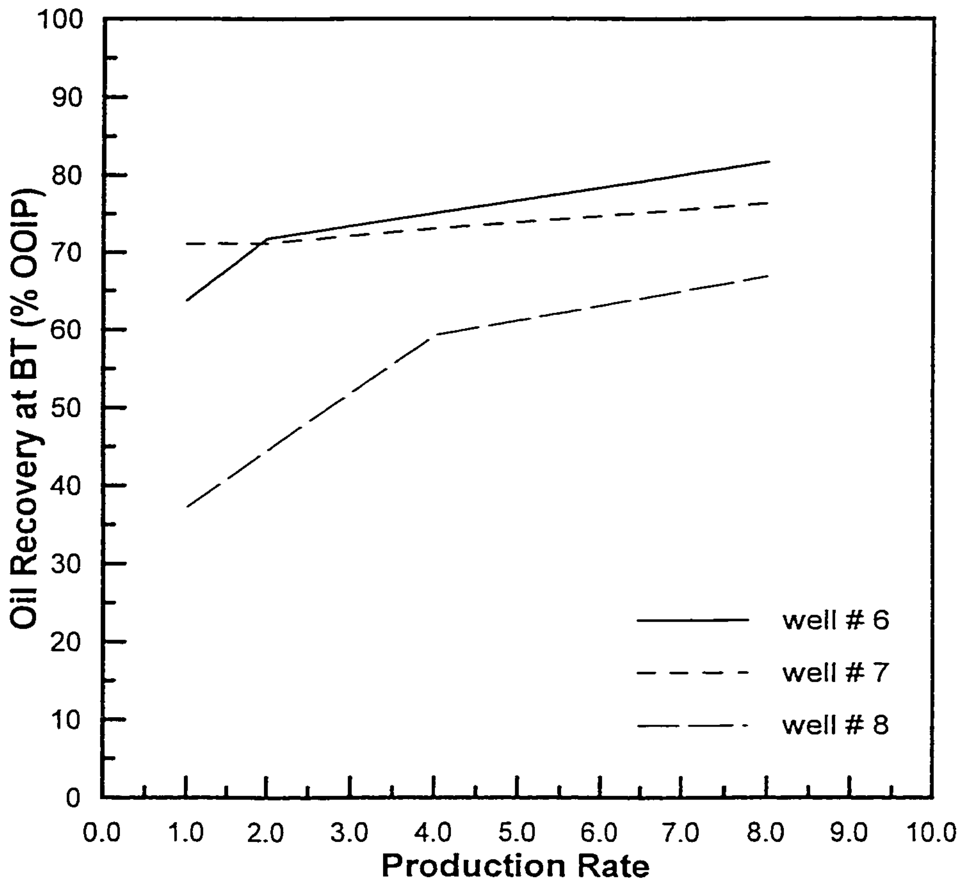

Figure 5.39: Oil Recovery at breakthrough versus production rate at different well locations for SWGD

occurs last for it because it is farthest from the water/oil interface.

5.3.3 Water-Cut

The results of water-cut as a function of time and of recovery for different well locations are presented in figures 5.40 to 5.45. These figures illustrate the effect of the production rate on the water-cut for each well-location. These results show that the water production starts earlier for higher production rates. However, unlike BWD the recovery at breakthrough is higher for higher production rates. The increase in water production is very sharp for almost all the cases and within 10 minutes of breakthrough the water-cut becomes more than 90% for all the cases. The same results are shown in figures 5.46 to 5.53 to illustrate the effect of well location on the water-cut for the various production rates studied. In continuation of the previous discussion about the oil recovery and breakthrough time results, these also show similar trends. At higher rates well # 6 starts water production later than well # 7 and 8 because of a later breakthrough.

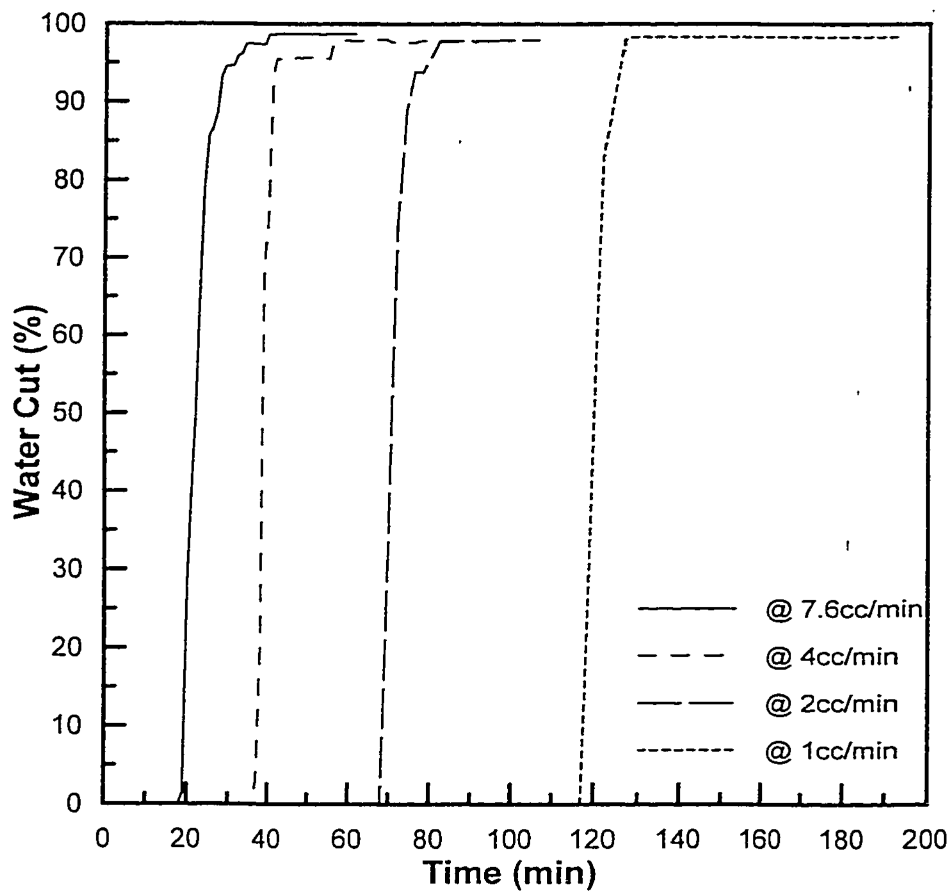

Figure 5.40: Comparison of Water-Cut versus Time for Well # 6 at different production rates for SWGD

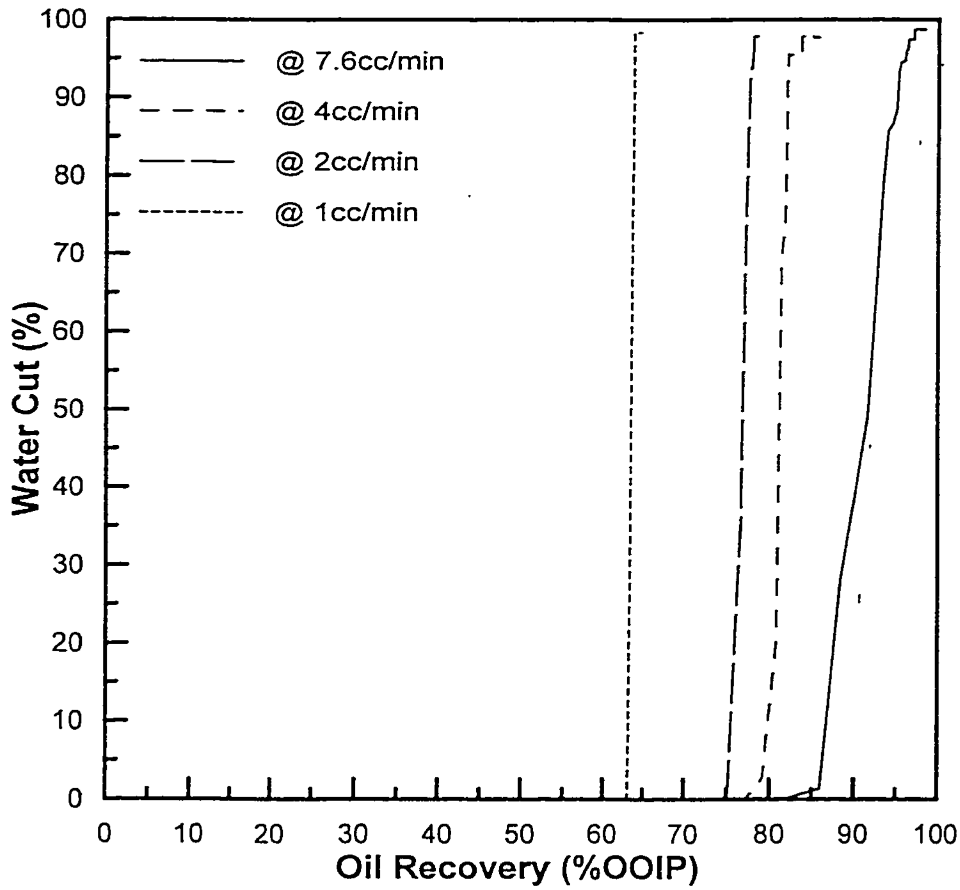

Figure 5.41: Comparison of water-cut versus oil recovery for Well # 6 at different production rates for SWGD

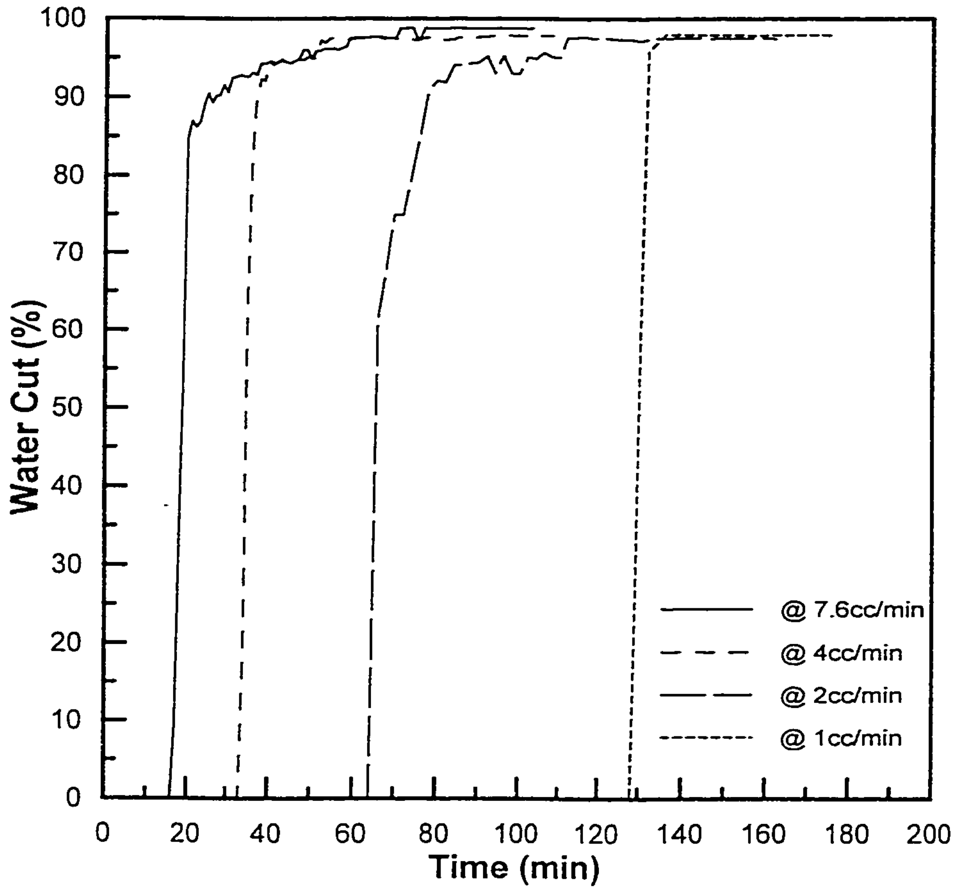

Figure 5.42: Comparison of water-cut versus time for well # 7 at different production rates for SWGD

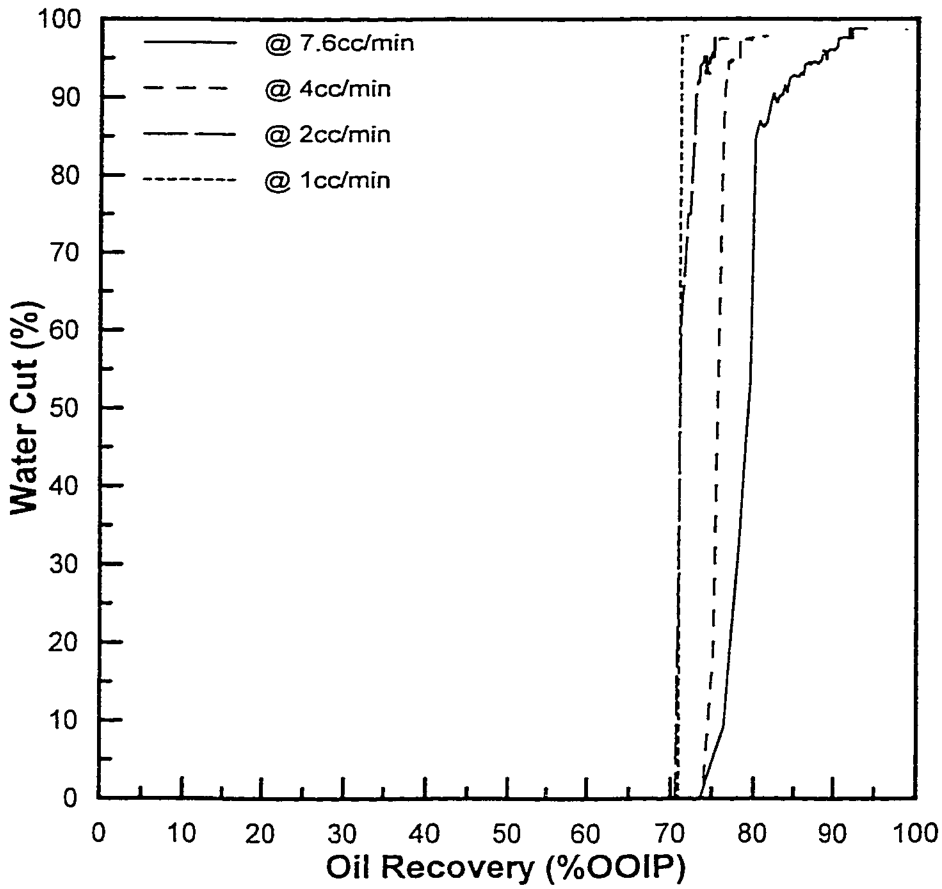

Figure 5.43: Comparison of water-cut versus oil recovery for Well # 7 at different production rates for SWGD

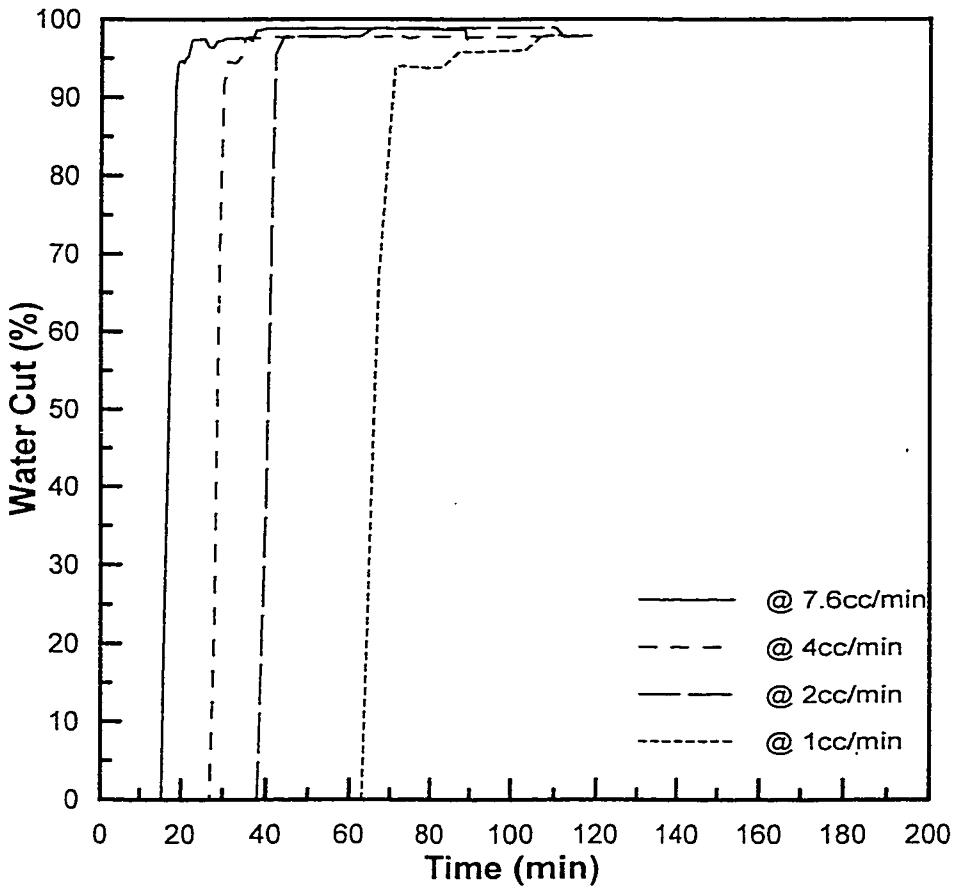

Figure 5.44: Comparison of water-cut versus time for Well # 8 at different production rates for SWGD

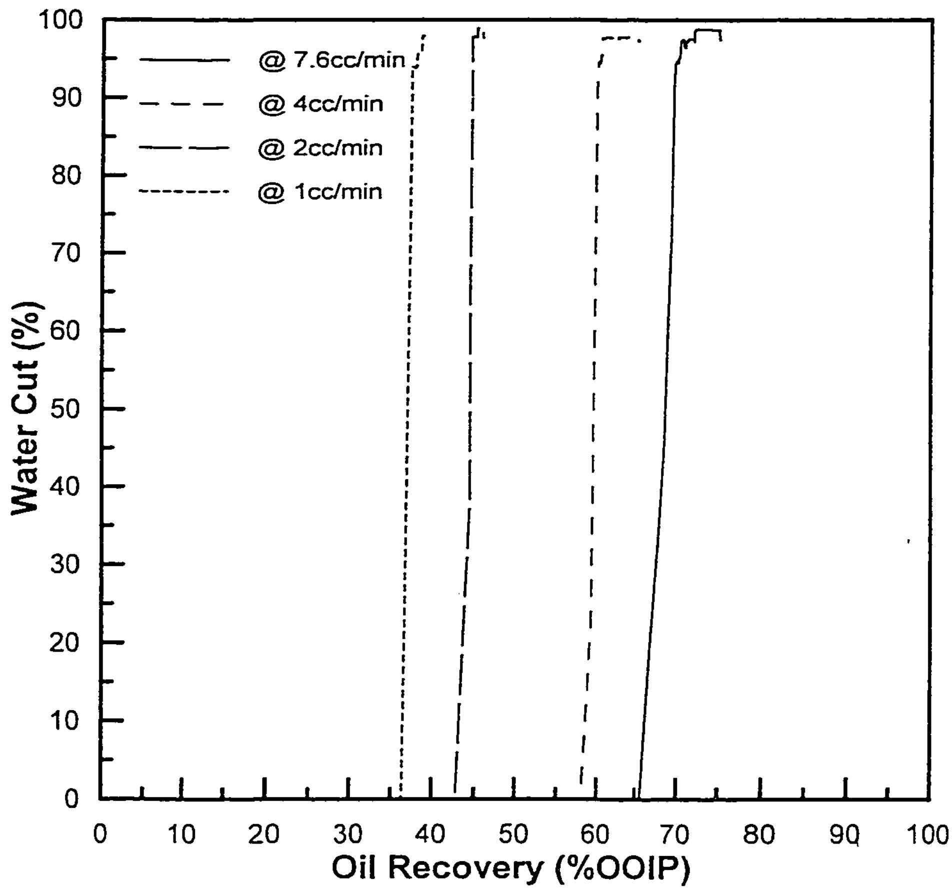

Figure 5.45: Comparison of water-cut versus oil recovery for Well # 8 at different production rates for SWGD

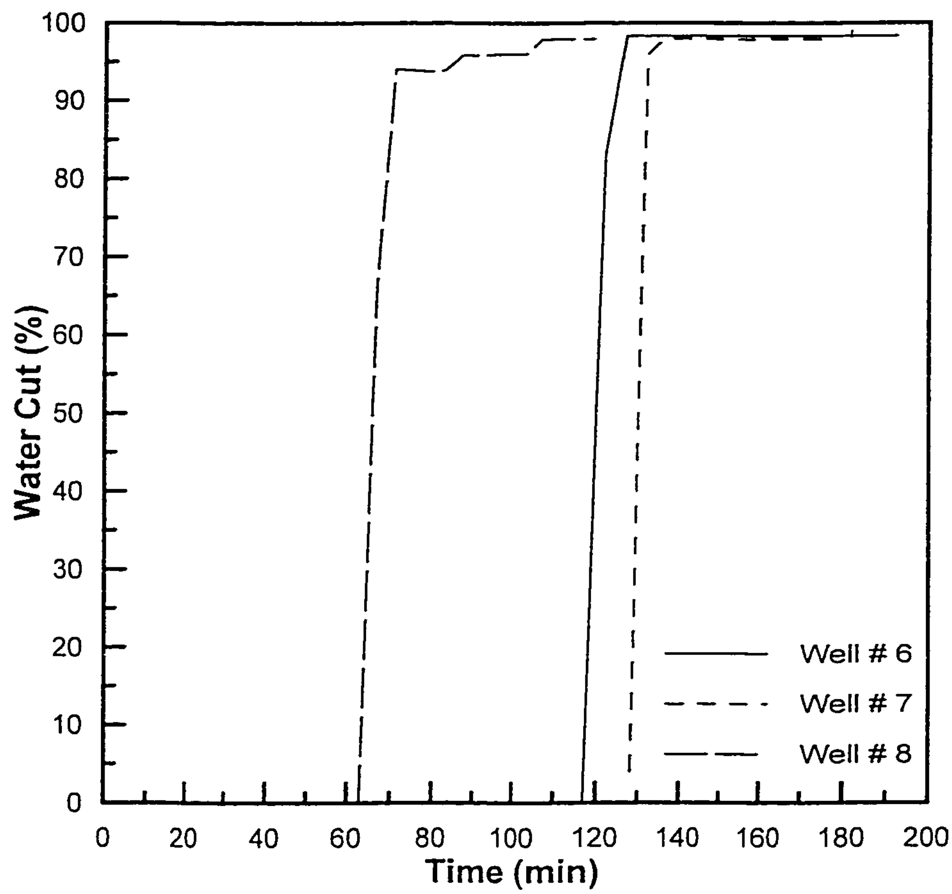

Figure 5.46: Comparison of Water-Cut versus Time at 1cc/min from different well locations for SWGD

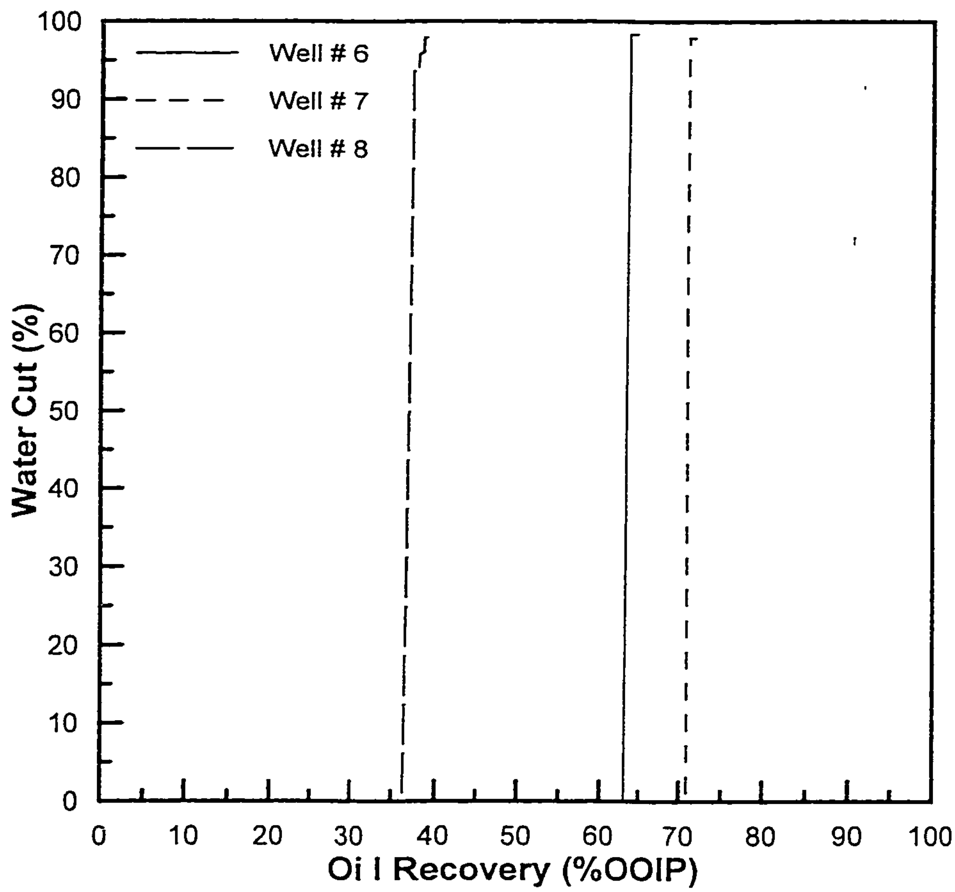

Figure 5.47: Comparison of water-cut versus oil recovery at 1cc/min from different well locations for SWGD

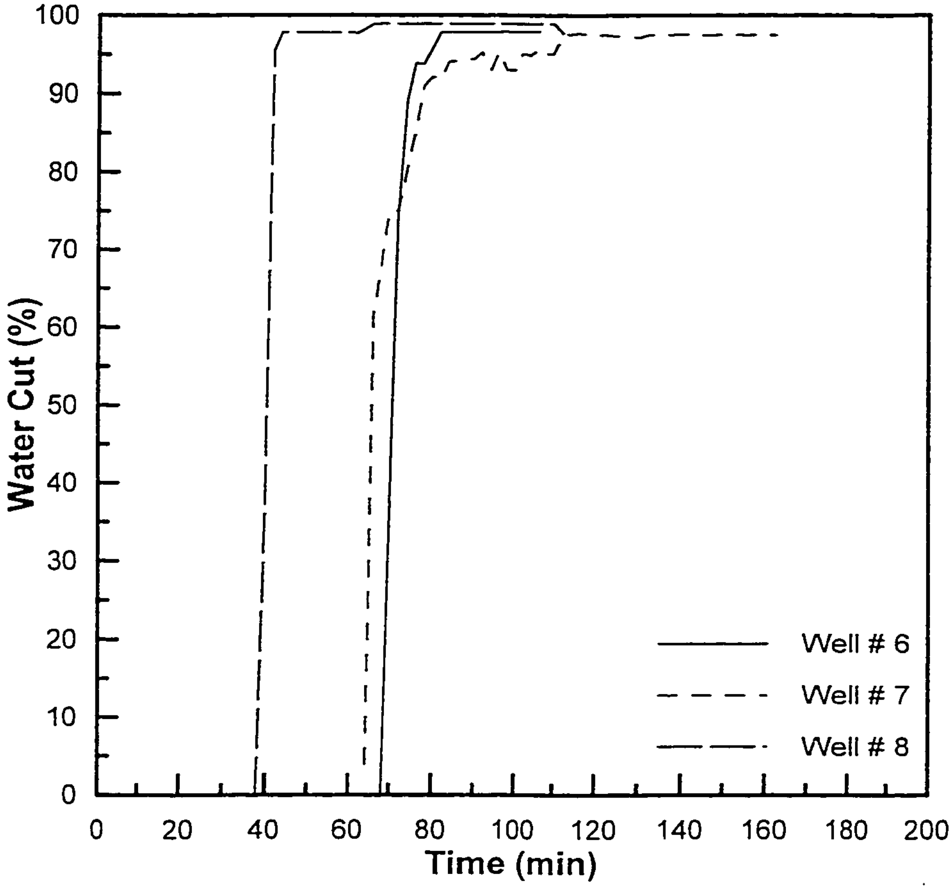

Figure 5.48: Comparison of water-cut versus time at 2cc/min from different well locations for SWGD

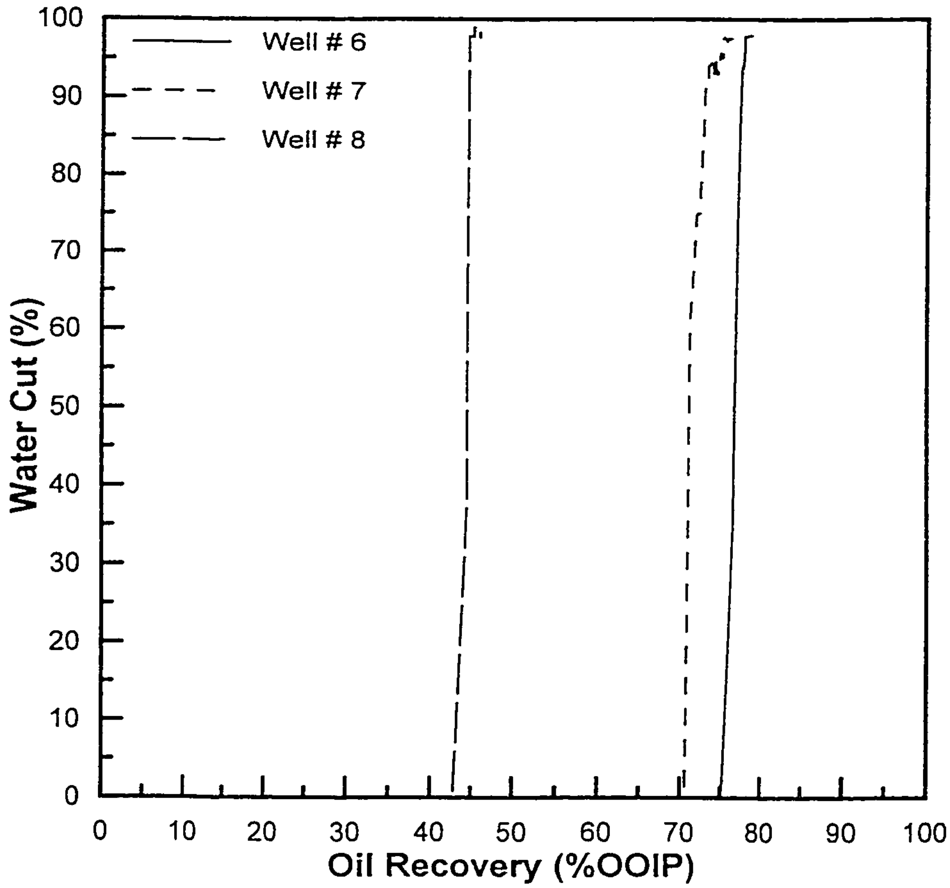

Figure 5.49: Comparison of water-cut versus oil recovery at 2cc/min from different well locations for SWGD

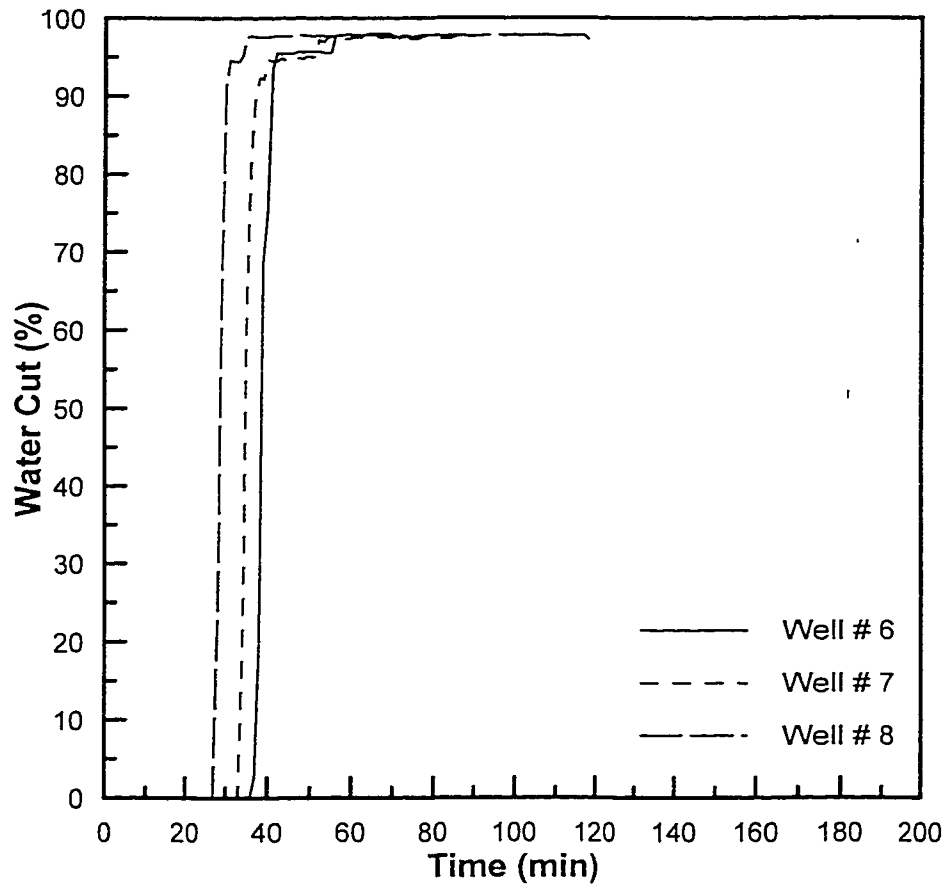

Figure 5.50: Comparison of water-cut versus time at 4cc/min from different well locations for SWGD

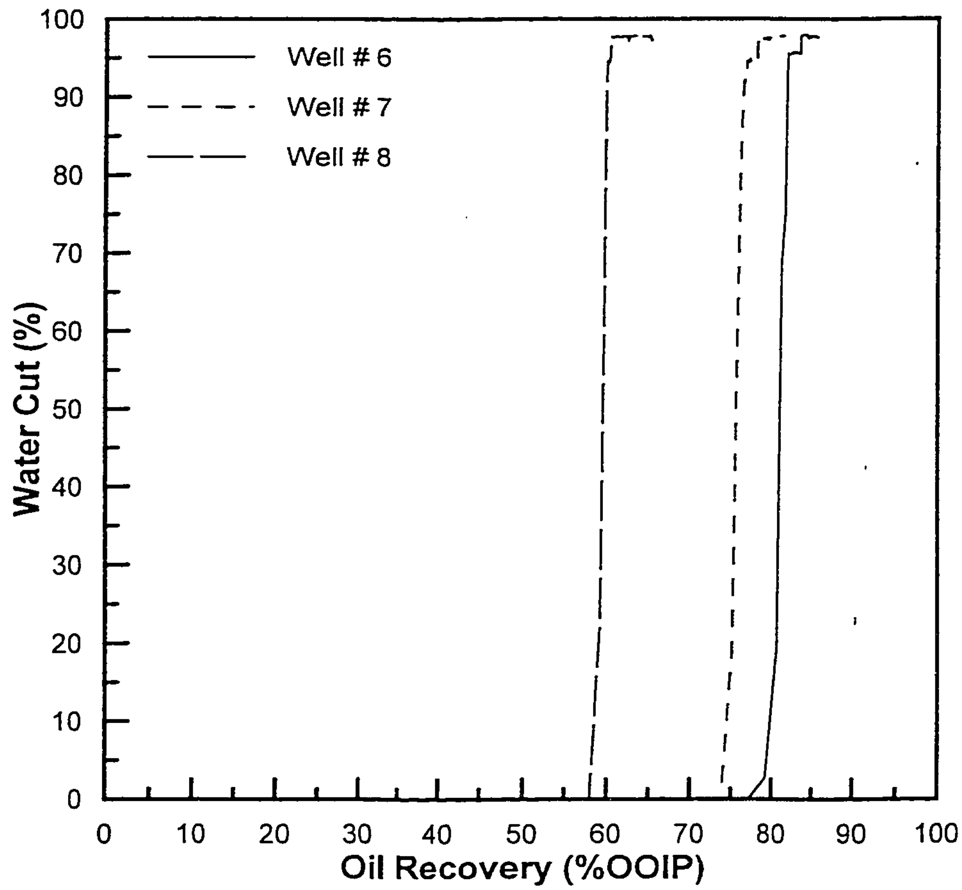

Figure 5.51: Comparison of water-cut versus oil recovery at 4cc/min from different well locations for SWGD

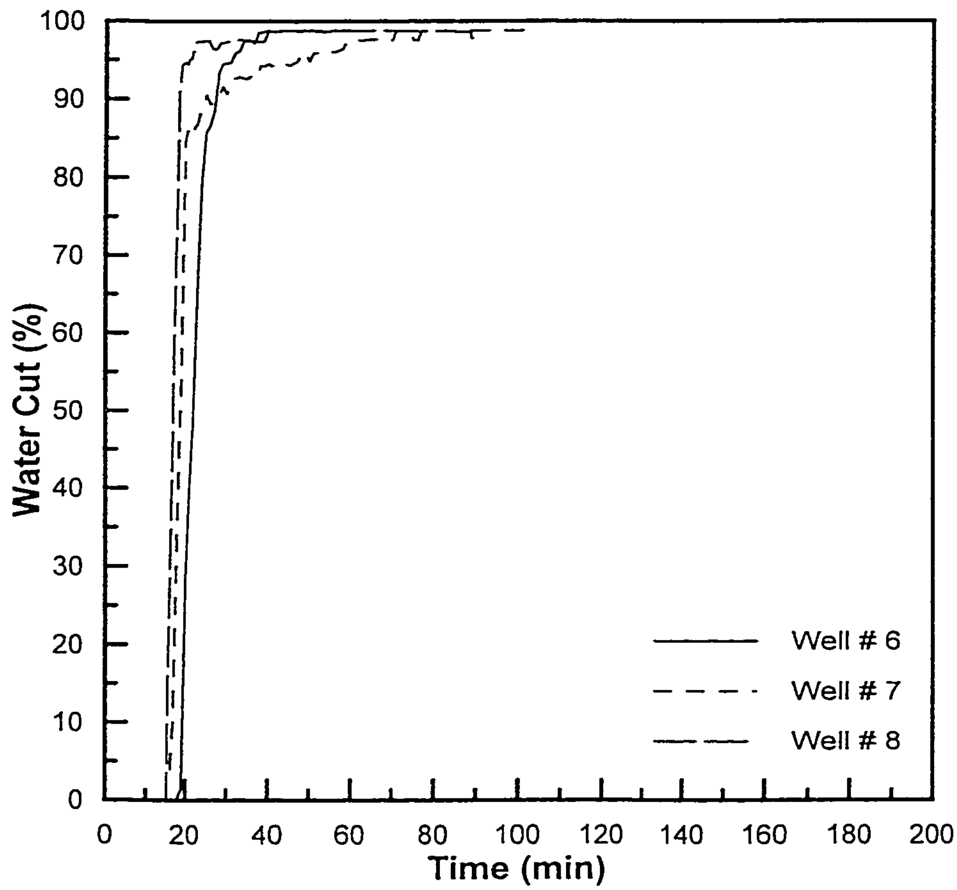

Figure 5.52: Comparison of water-cut versus time at 7.6cc/min from different well locations for SWGD

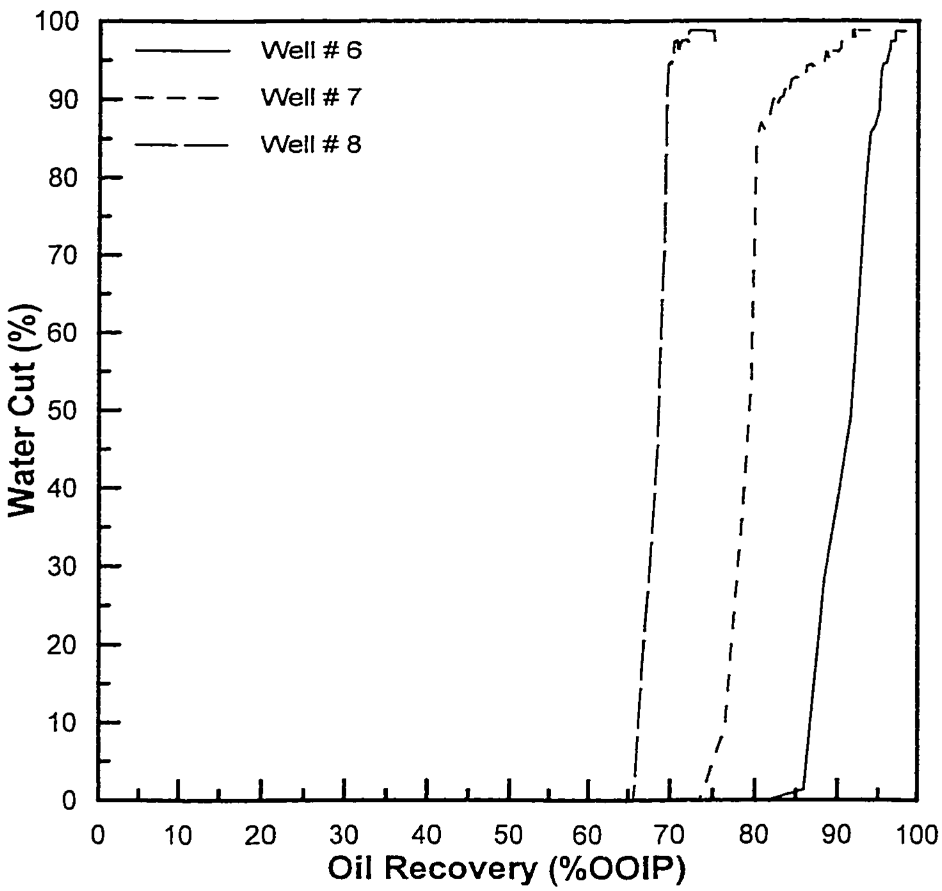

Figure 5.53: Comparison of water-cut versus oil recovery at 7.6cc/min from different well locations for SWGD

5.3.4 Pressure Distribution

The pressure distributions (figures 5.54 to 5.67) are presented here as a set of two types of graphs, one having the inlet and differential pressures for the gas and the other for the water. In case of the water the inlet pressure is presented as a constant pressure line of 3.4 psig that is equal to the head of the water that is applied at the point of the water inlet. These calculations are presented in section 4.1.3 where the gas and the water storage systems are discussed. The results show that at a given well location (figures 5.54 to 5.59) the gas pressure decreases as the production rate increases and the differential pressure on both sides, that is, gas and water increases with increasing production rate. The reason is that the high production rate causes the gas-cap pressure to decline rapidly. As discussed earlier, the gas-cap pressure is actually depleting itself and there is no re-injection of the gas once the experiment starts. The pressure drop on the water side is also higher for higher rates in agreement with the discussion in section 5.1.4 and the results of figure 5.9.

Figures 5.60 to 5.67 show the effect of the well location on the pressure distribution. It is observed that the gas pressure at all the rates is higher for well # 7 and those for well # 6 and 8 closely follow behind. The major decline occurs during the first 10 minutes and then it just trails off in a gradually decreasing manner. For lower rates the values stay above 1.5 psig but at the higher rate of 4 cc/min they fall below and even touch up to 1.25 psig for the highest rate of 7.6 cc/min.

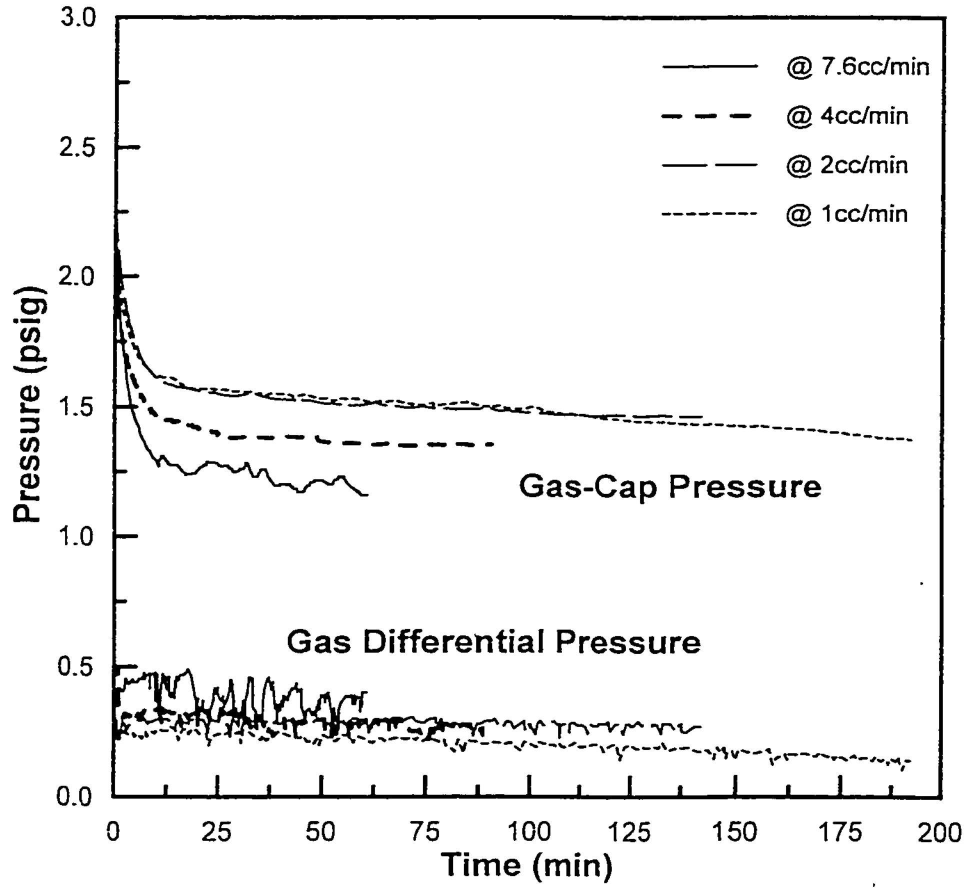

Figure 5.54: Gas inlet and differential pressures for well # 6 at different production rates for SWGD.

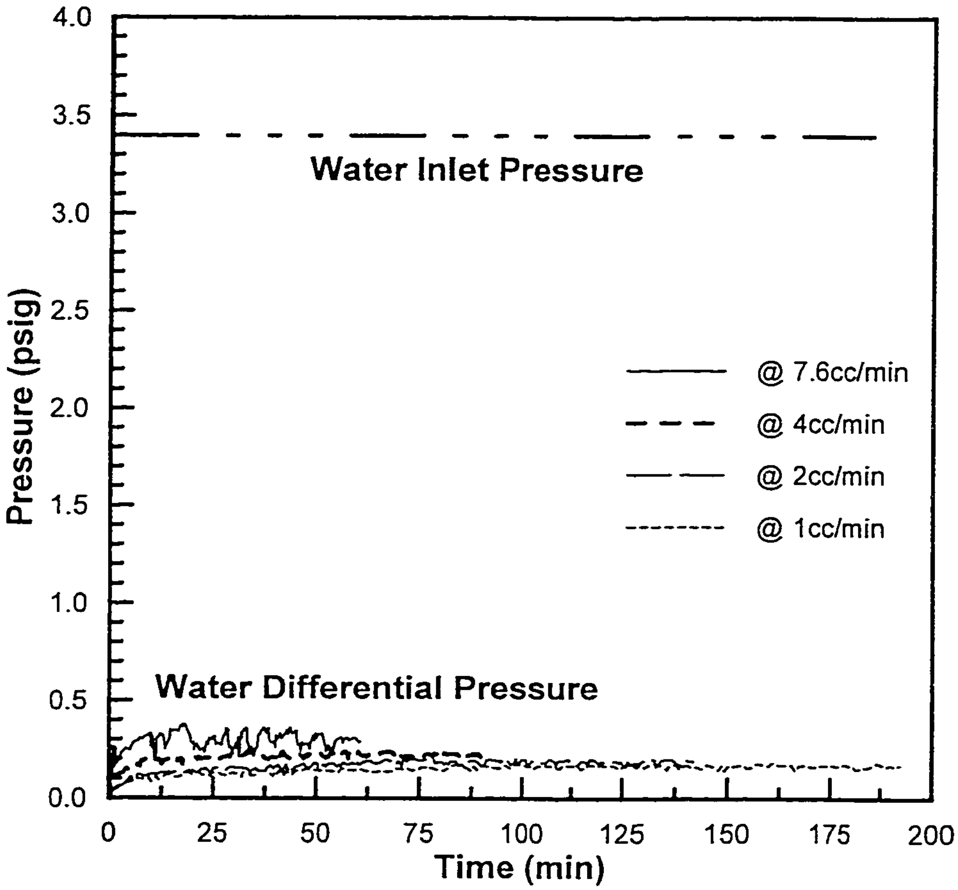

Figure 5.55: Water inlet and differential pressures for well # 6 at different production rates for SWGD.

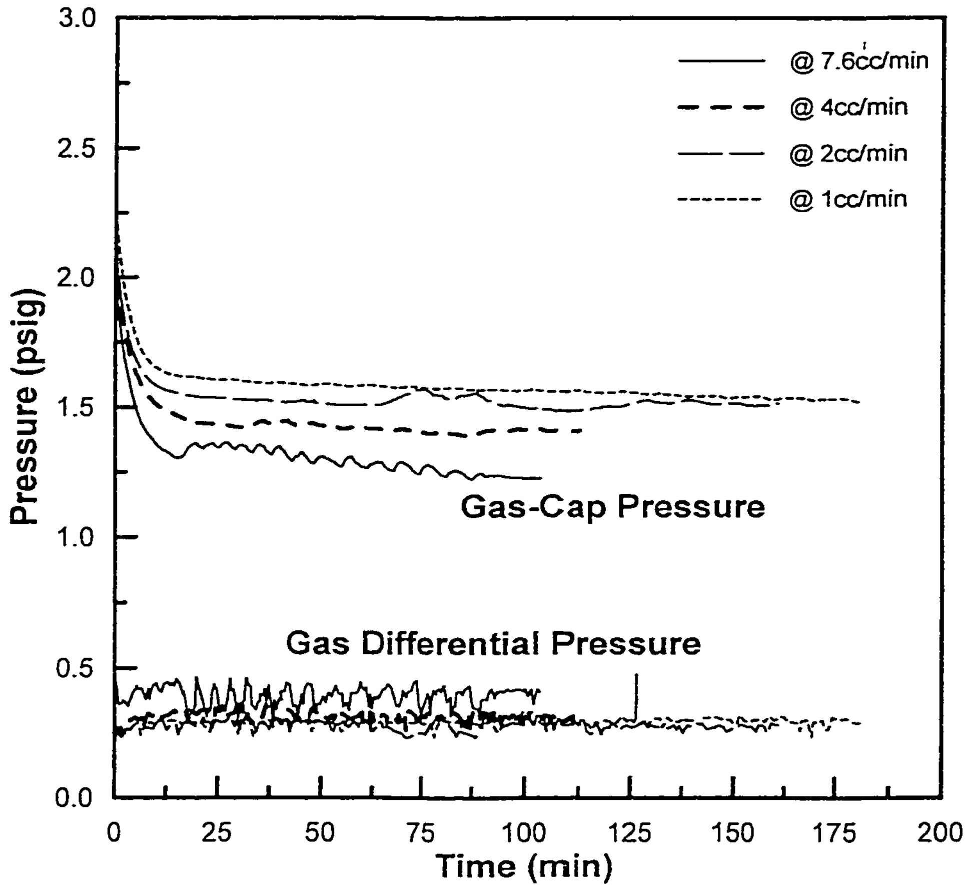

Figure 5.56: Gas inlet and differential pressures for well # 7 at different production rates for SWGD.

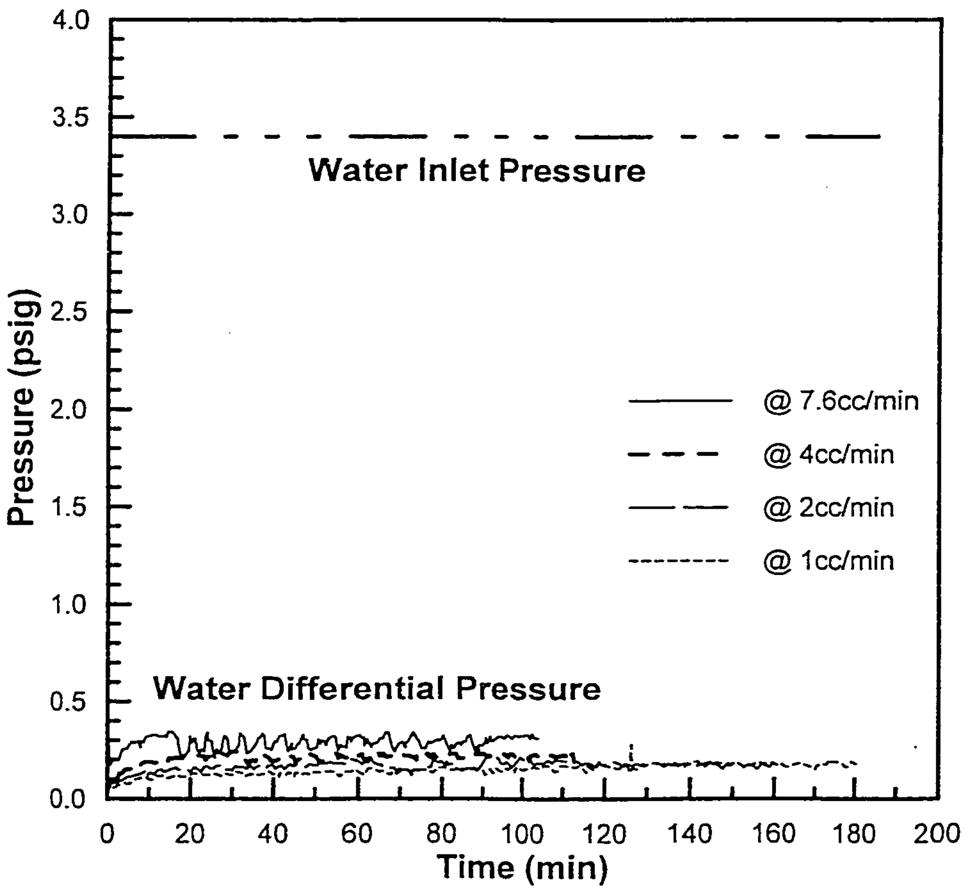

Figure 5.57: Water inlet and differential pressures for well # 7 at different production rates for SWGD.

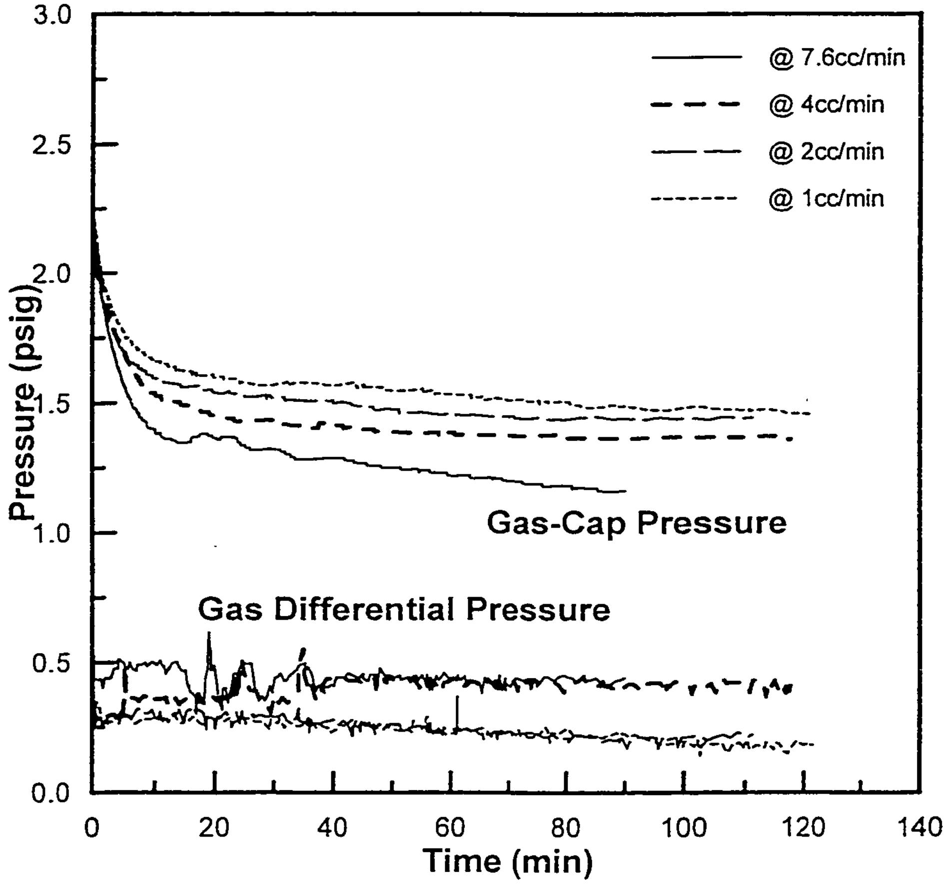

Figure 5.58: Gas-cap and gas differential pressures for well # 8 at different production rates for SWGD.

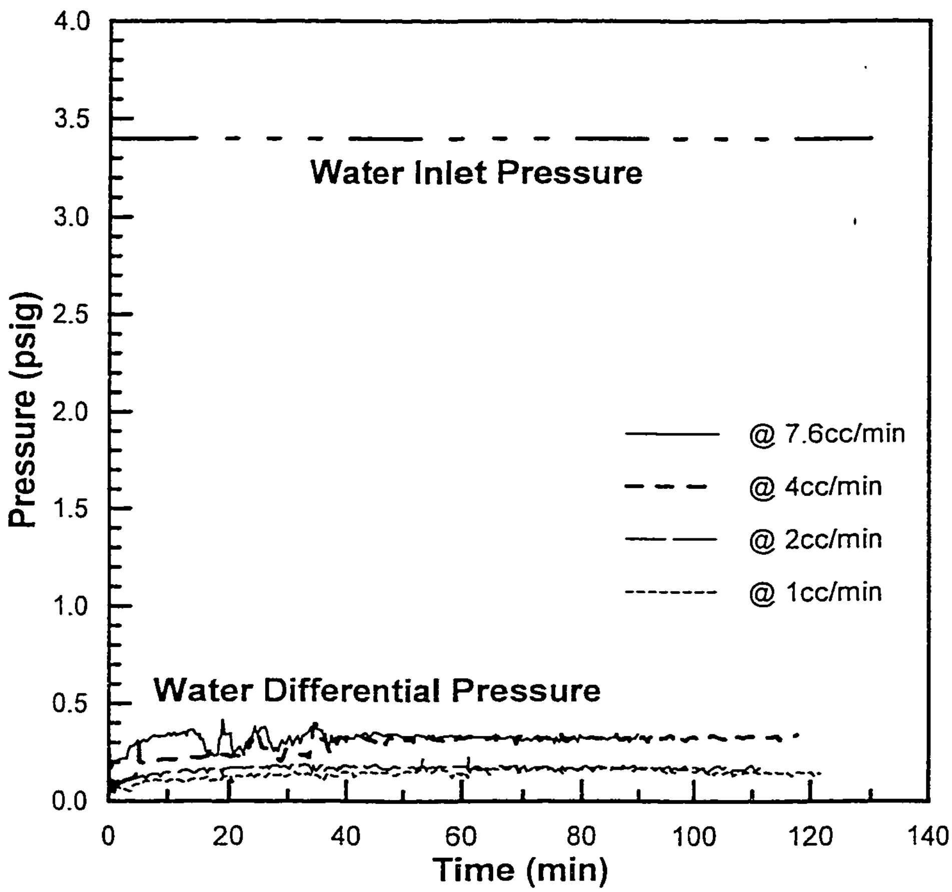

Figure 5.59: Water inlet and differential pressures for well # 8 at different production rates for SWGD.

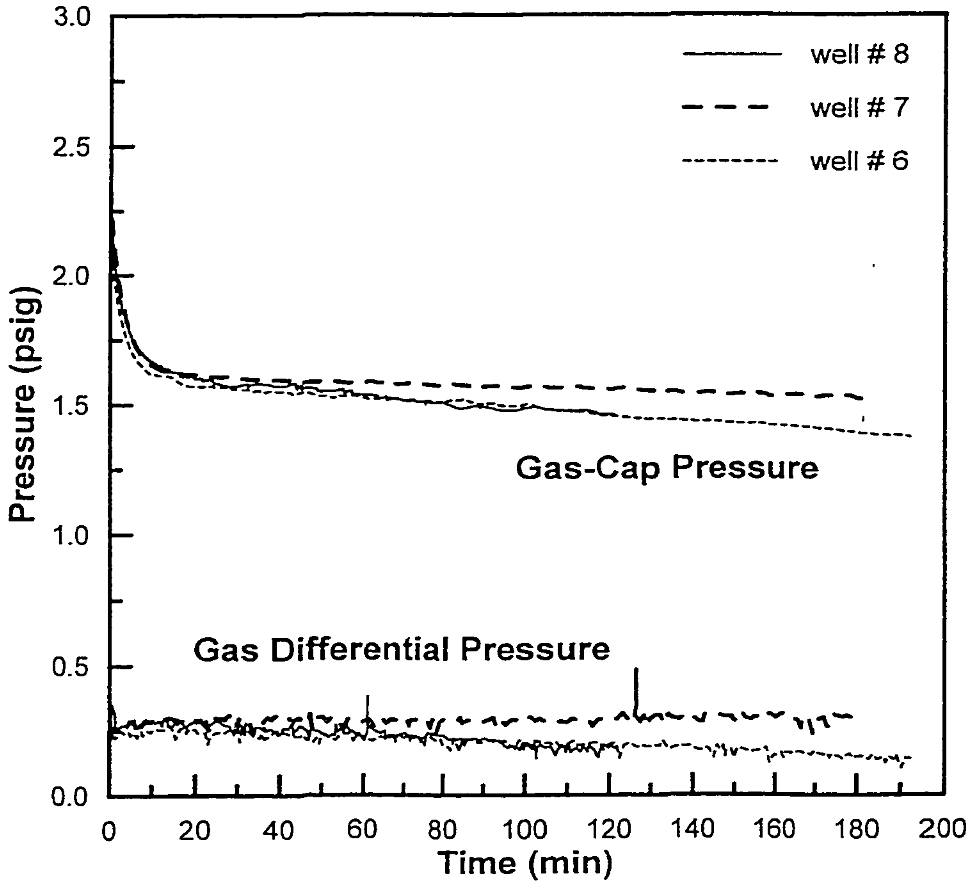

Figure 5.60: Gas-cap and gas differential pressures at 1cc/min for different well locations for SWGD.

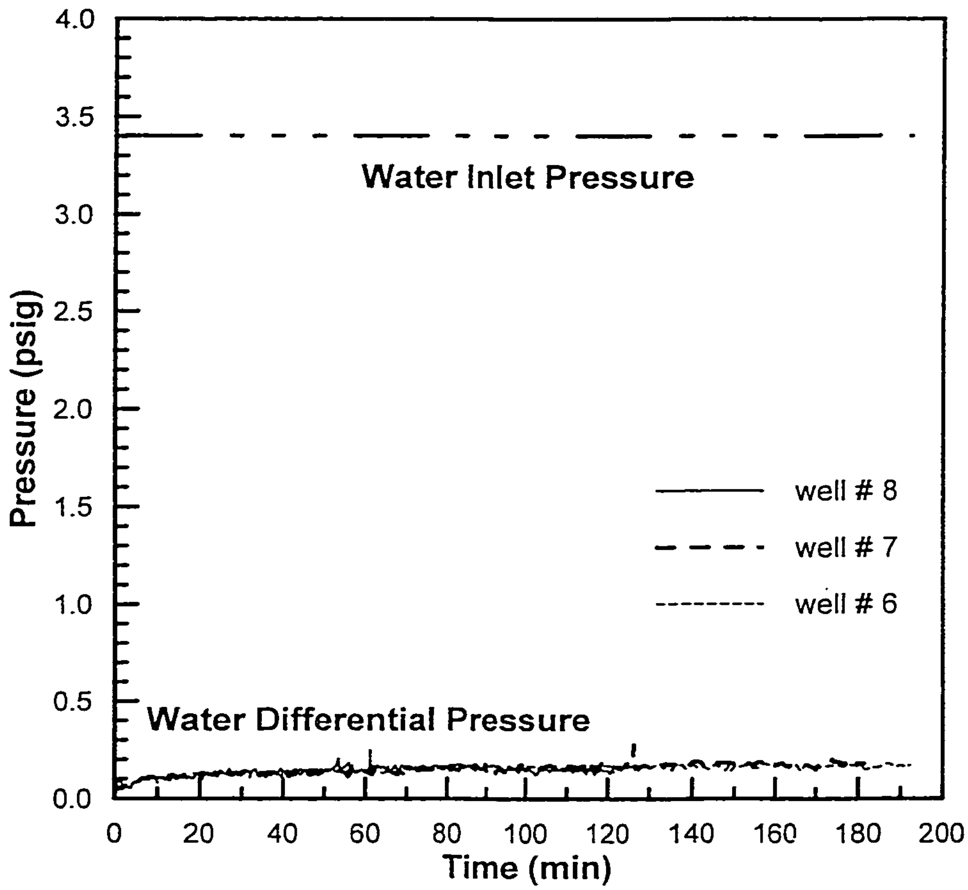

Figure 5.61: Water inlet and differential pressures 1cc/min for different well locations for SWGD.

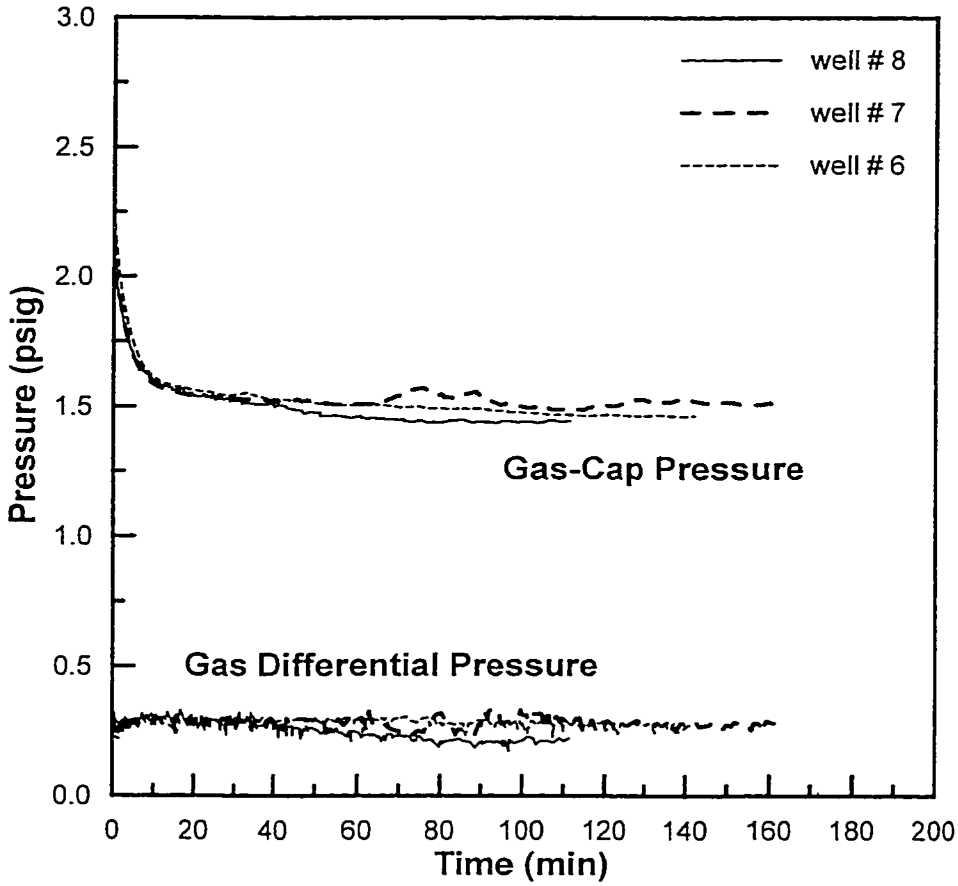

Figure 5.62: Gas-cap and gas differential pressures at 2cc/min for different well locations for SWGD.

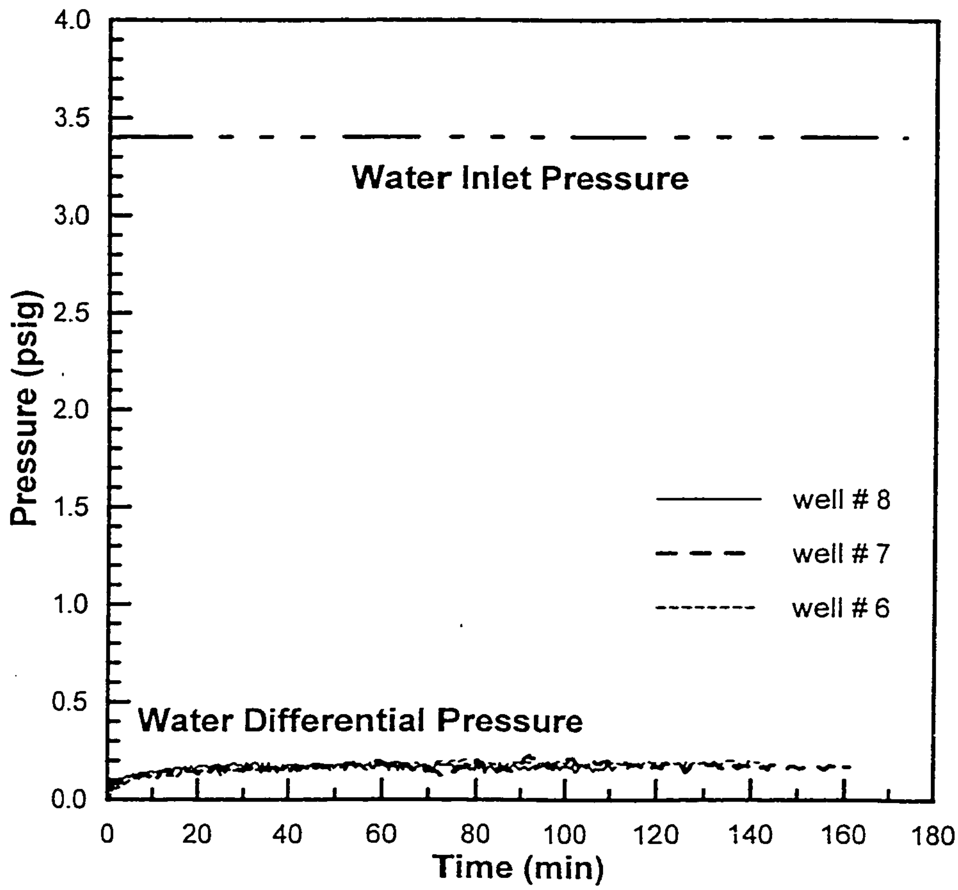

Figure 5.63: Water inlet and differential pressures 2cc/min for different well locations for SWGD.

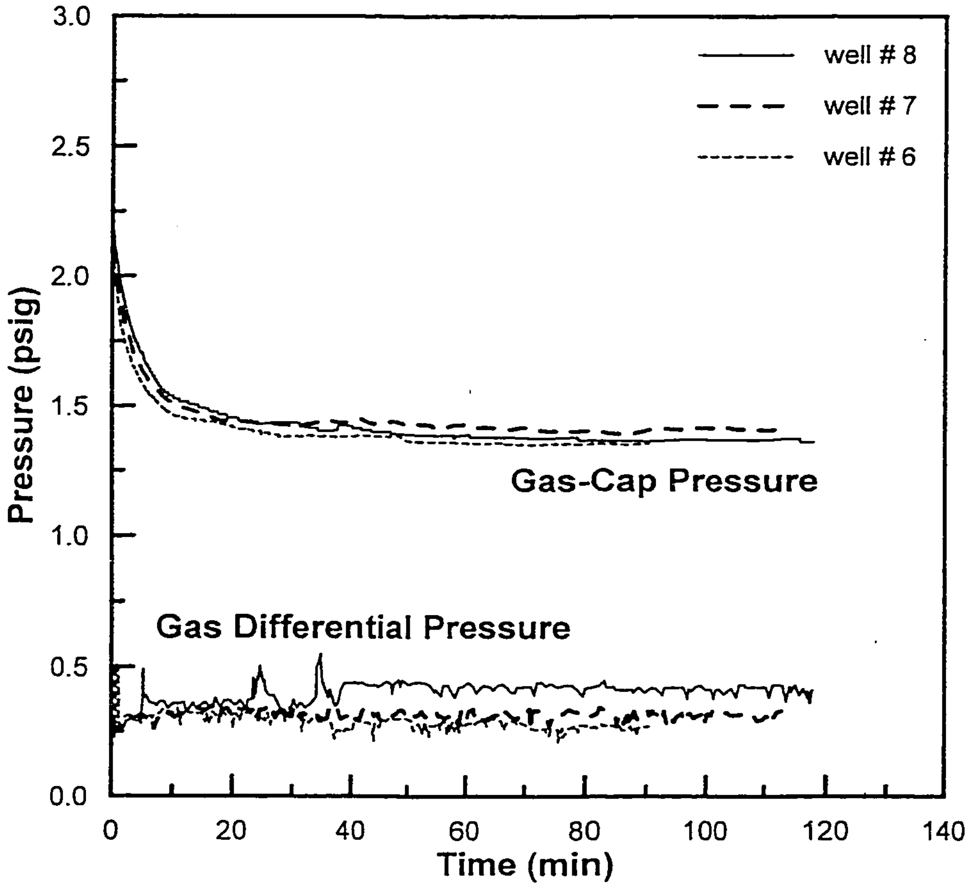

Figure 5.64: Gas-cap and gas differential pressures at 4cc/min for different well locations for SWGD.

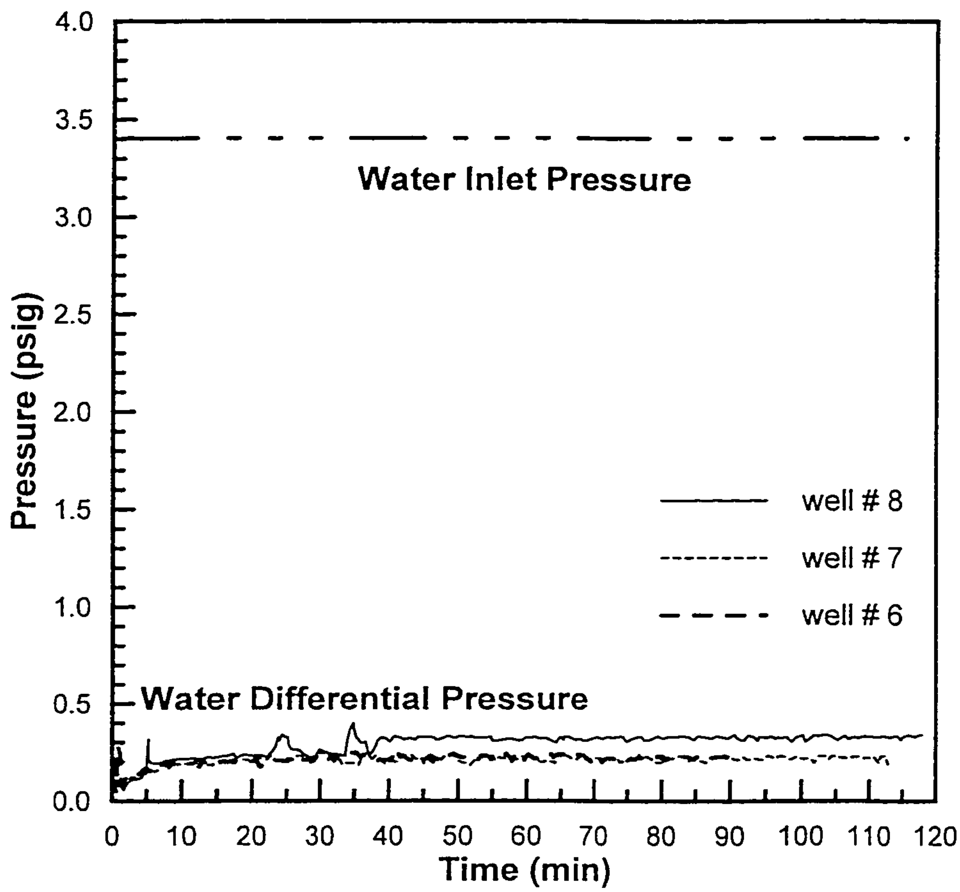

Figure 5.65: Water inlet and differential pressures 4cc/min for different well locations for SWGD.

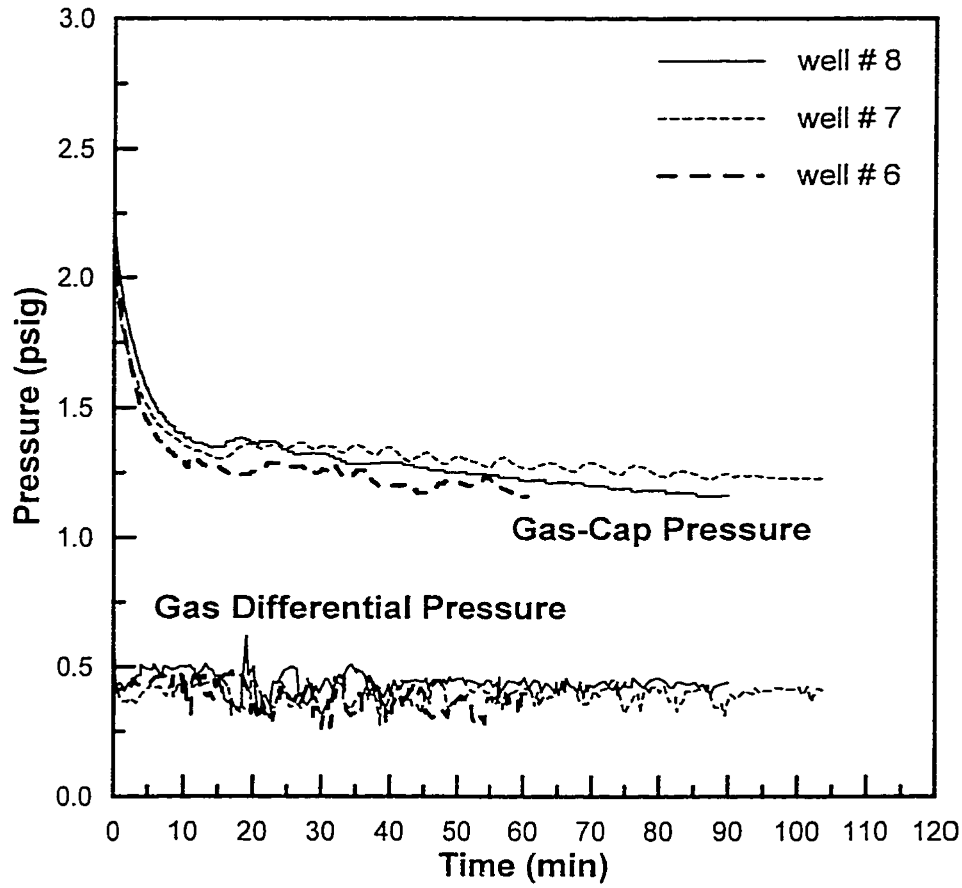

Figure 5.66: Gas-cap and gas differential pressures at 7.6cc/min for different well locations for SWGD.

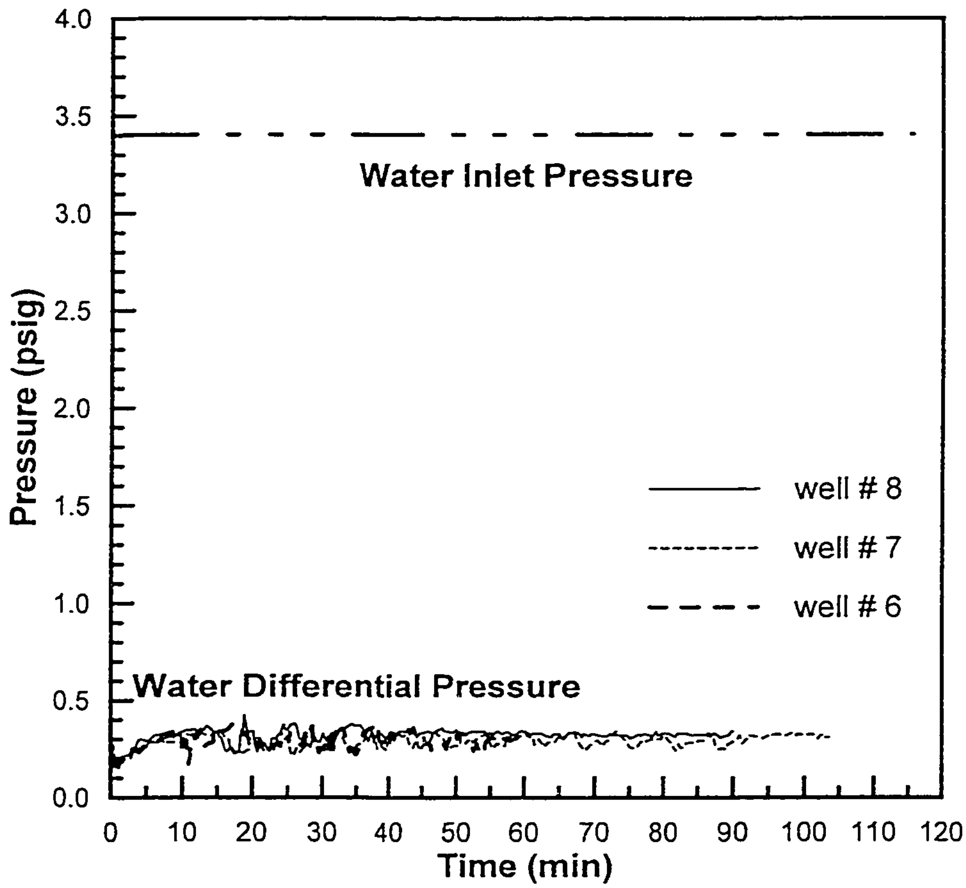

Figure 5.67: Water inlet and differential pressures 7.6cc/min for different well locations for SWGD.

The gas differential pressure at different well locations for constant production rates shows an almost constant distribution with well # 7 having a distinctly higher value at 1 cc/min (figure 5.60) and well # 8 at 4cc/min and 7.6 cc/min (figures 5.64 and 5.66). At 2 cc/min (figure 5.62) the distributions for different wells are closely packed together and clear distinction between them is difficult. This means that the change of well location does not really have a marked effect on the gas pressure distributions as compared to the change in production rate that hence constitutes the major factor for the pressure drops. The results for water differential pressure also behave in a similar manner.

5.3.5 Interface Movement

Figures 5.68 to 5.79 present the results for the interface movement of the SWGD. All runs start with the gas/oil interface 2 cm from the top and the water/oil interface 4 cm from the bottom. The gas/oil interface drops sharply with the start of the run and then moves gradually towards the well. This initial sudden drop of gas-cap pressure is also observed in the gas-inlet pressure distributions presented in the previous section. Therefore, for the initial portion of the runs gas-cap pressure dominates the movement of the interfaces, in the sense that the gas/oil interface moves faster towards the well as compared to the water/oil interface.. After a while, the gas-cap pressure has lost most of its strength and thus stabilizes. It then just provides a sort of constant pressure boundary to the now dominant BWD. Therefore,

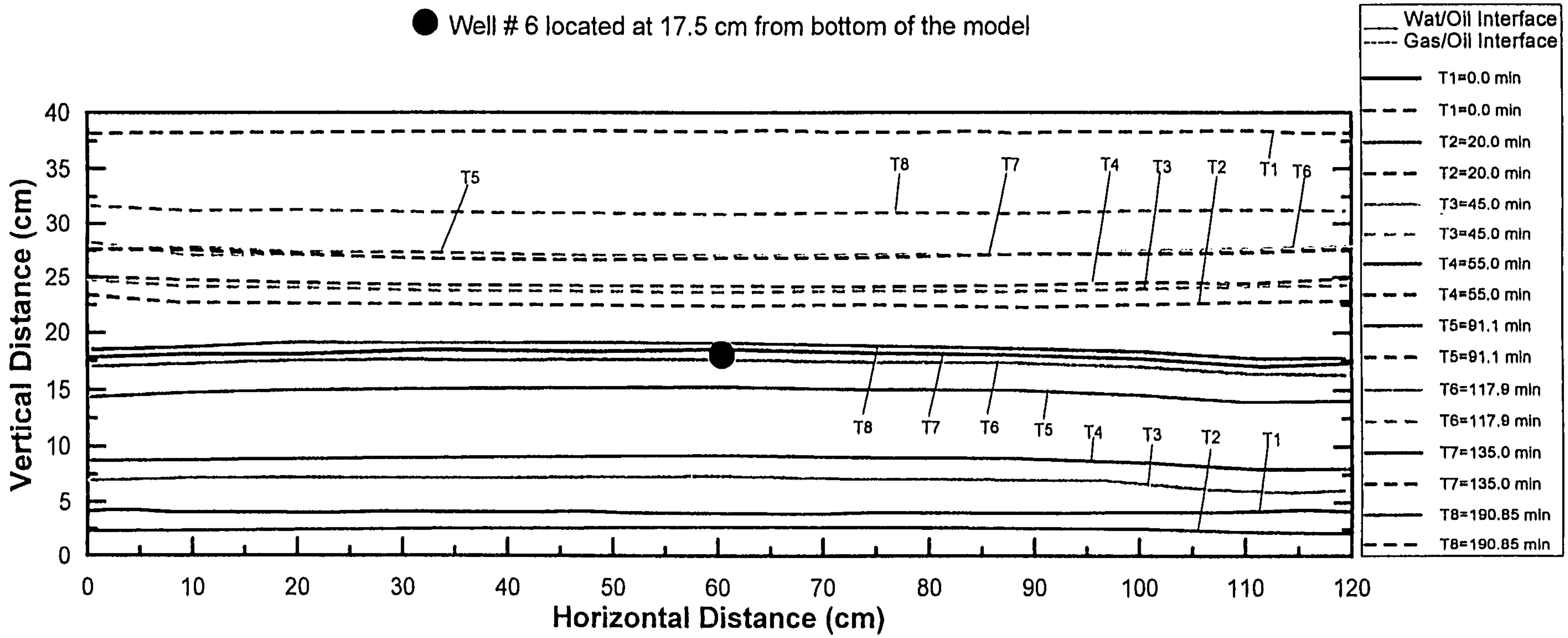

Figure 5.68(a): Interface movement for SWGD at 1cc/min from well # 6

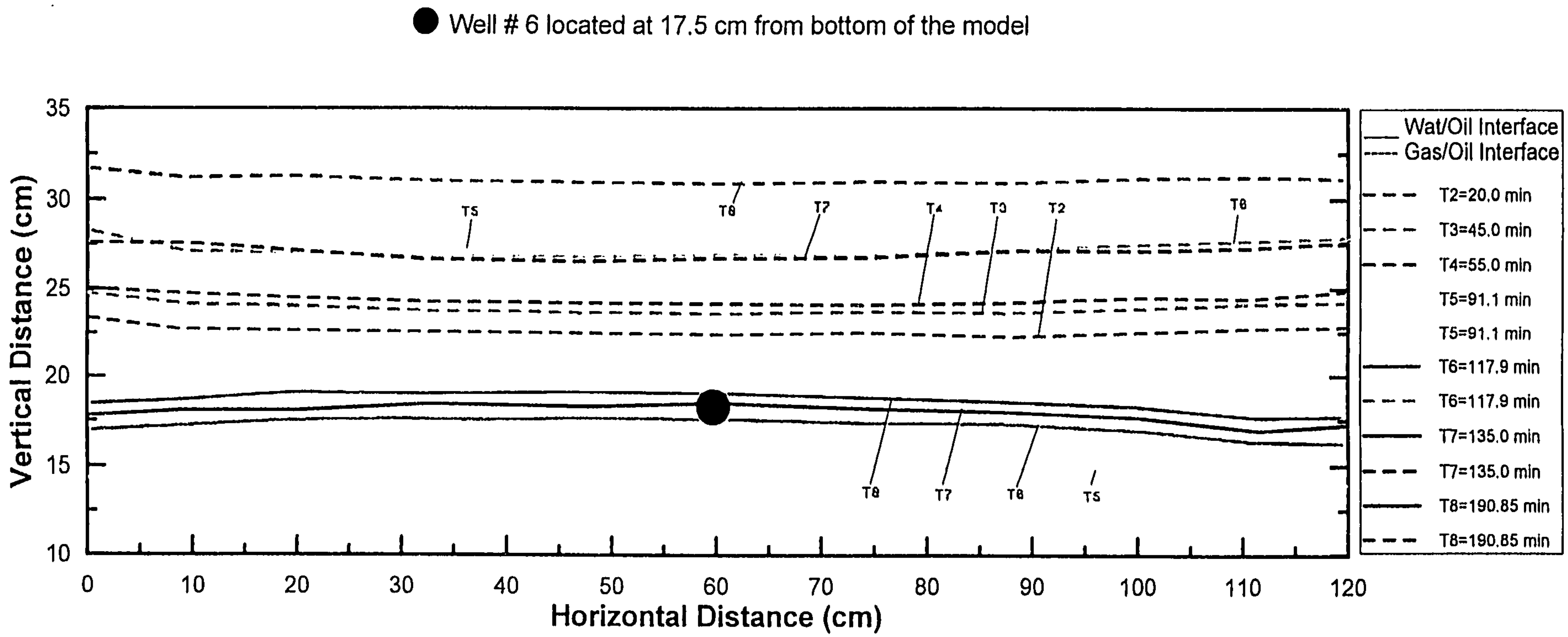

Figure 5.68(b): Enlarged vertical section of interface movement for SWGD at 1cc/min

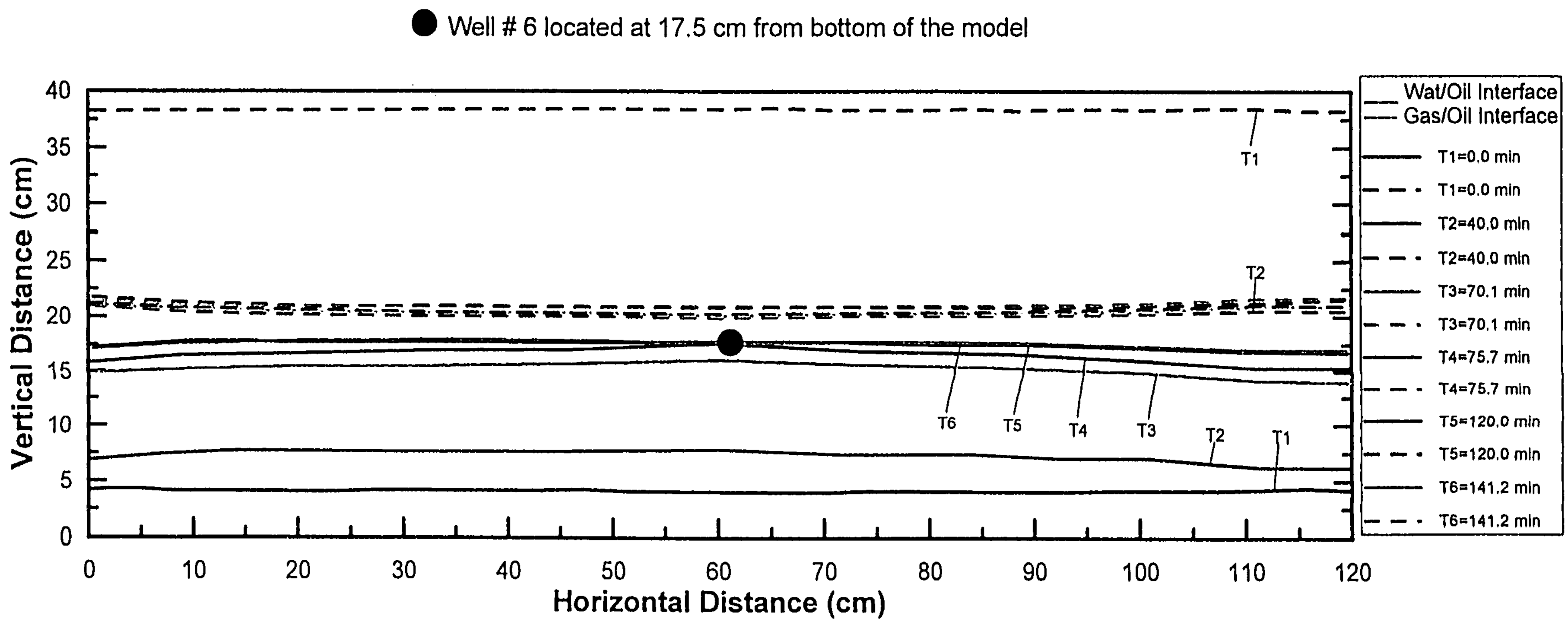

Figure 5.69(a): Interface movement for SWGD at 2cc/min from well # 6

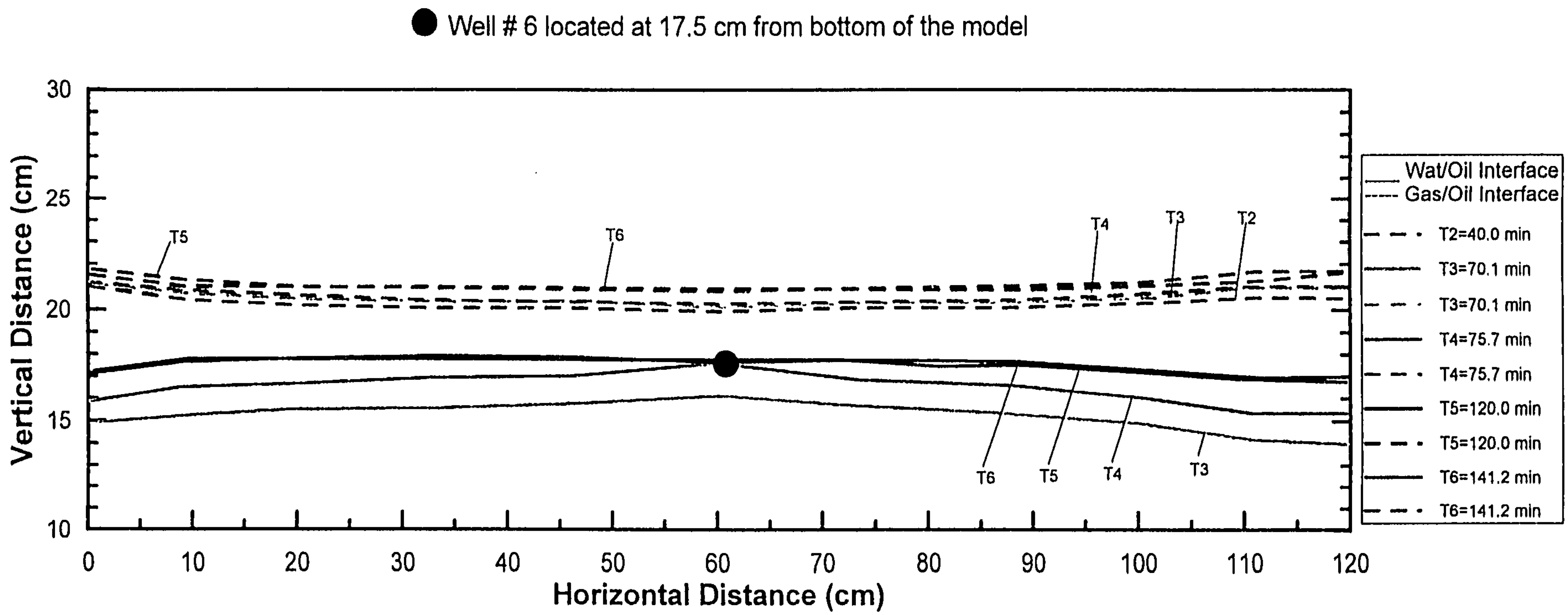

Figure 5.69(b): Enlarged vertical section of interface movement for SWGD at 2cc/min

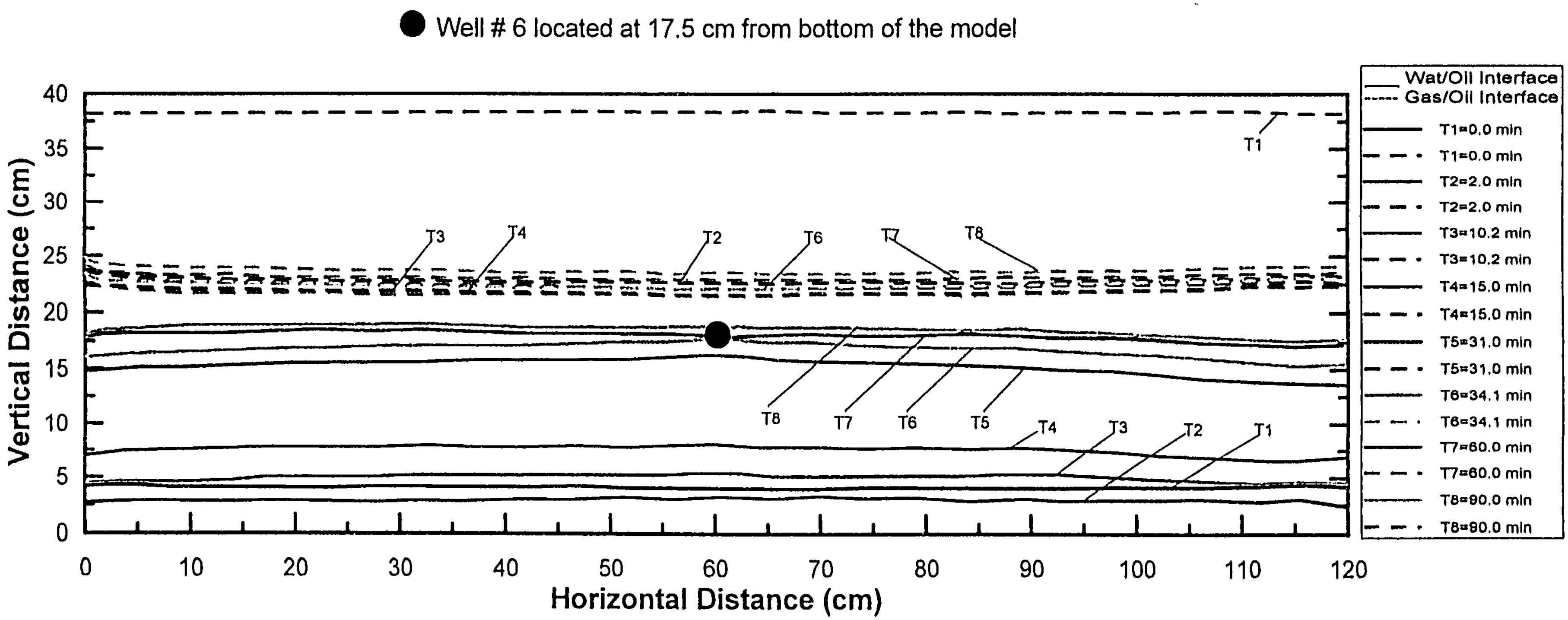

Figure 5.70(a): Interface movement for SWGD at 4cc/min from well # 6

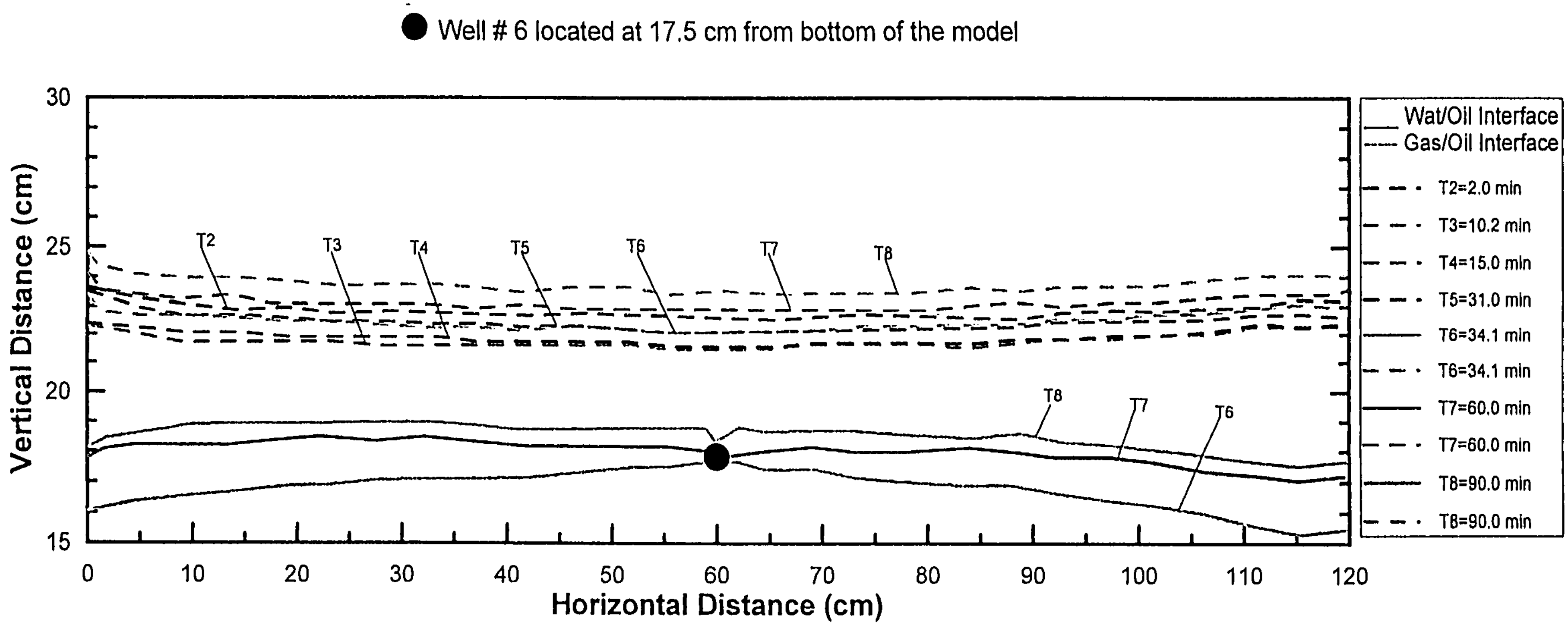

Figure 5.70(b): Enlarged vertical section of interface movement for SWGD at 4cc/min

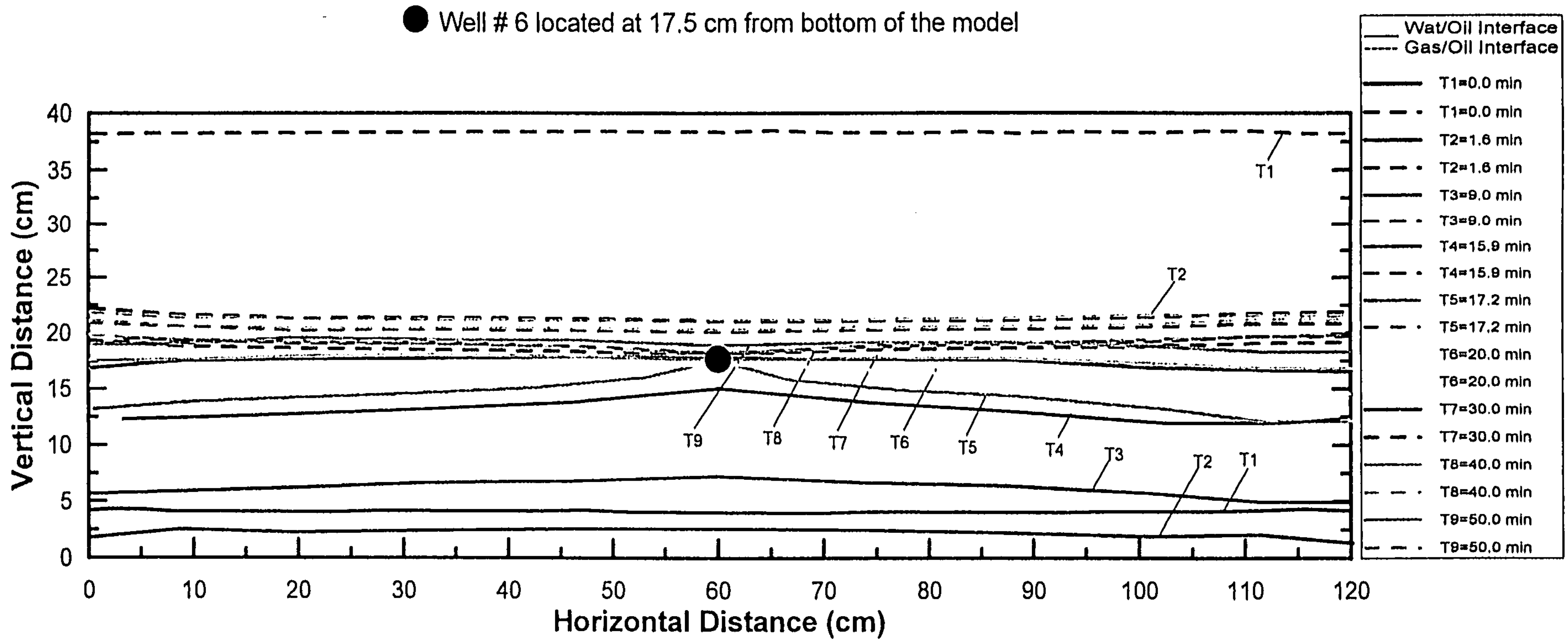

Figure 5.71(a): Interface movement for SWGD at 7.6cc/min from well # 6

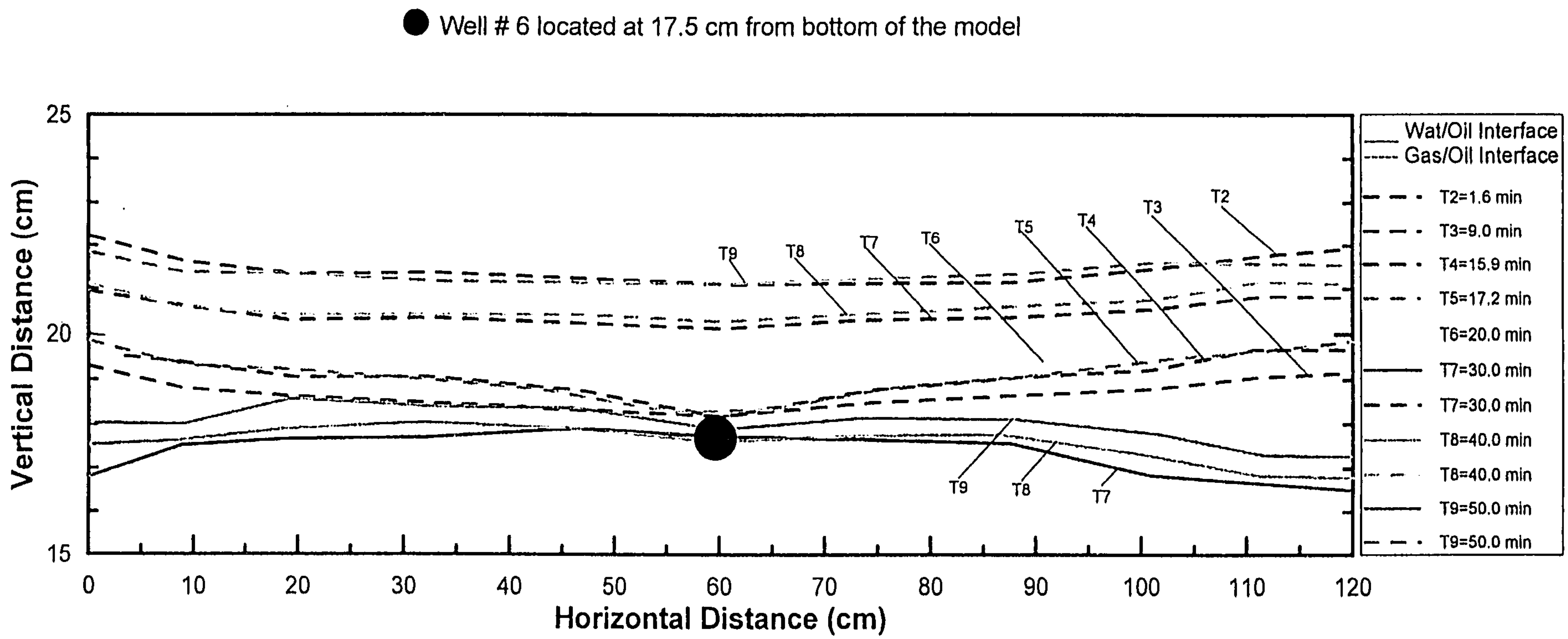

Figure 5.71(b): Enlarged vertical section of interface movement for SWGD at 7.6cc/min

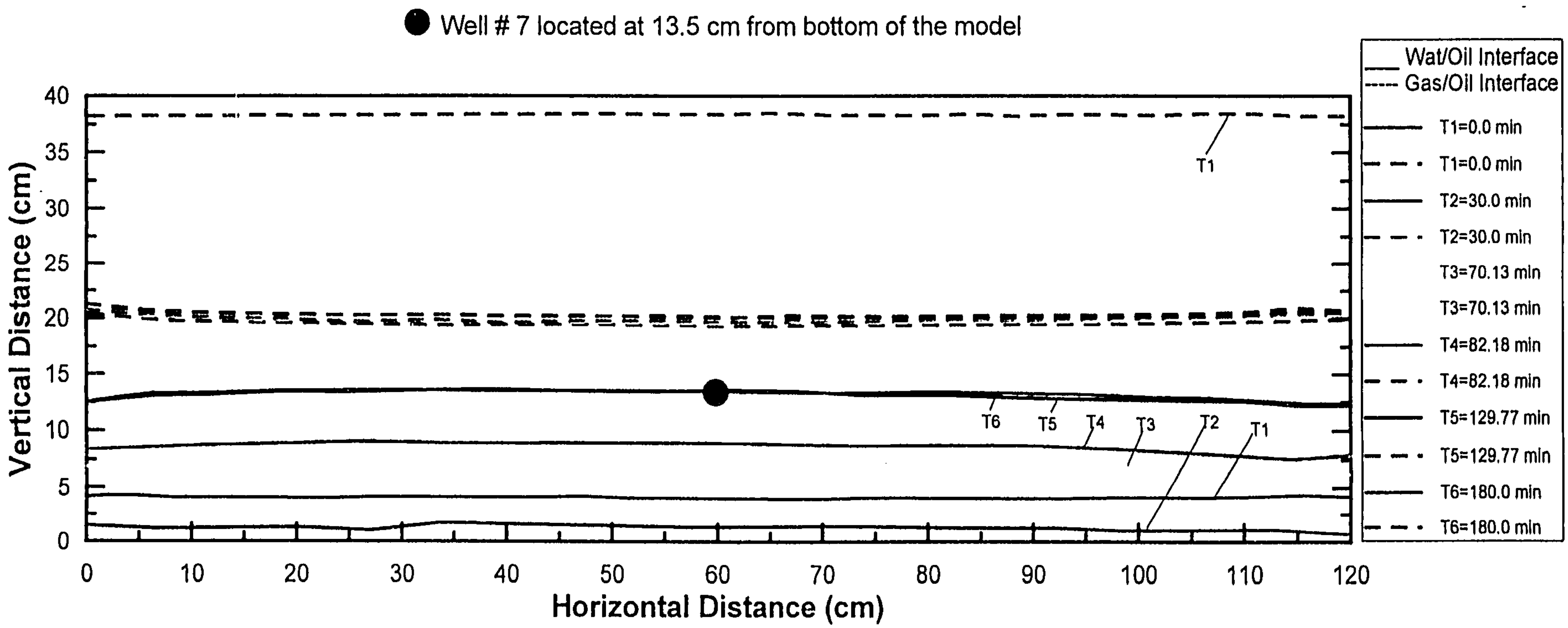

Figure 5.72(a): Interface movement for SWGD at 1cc/min from well # 7

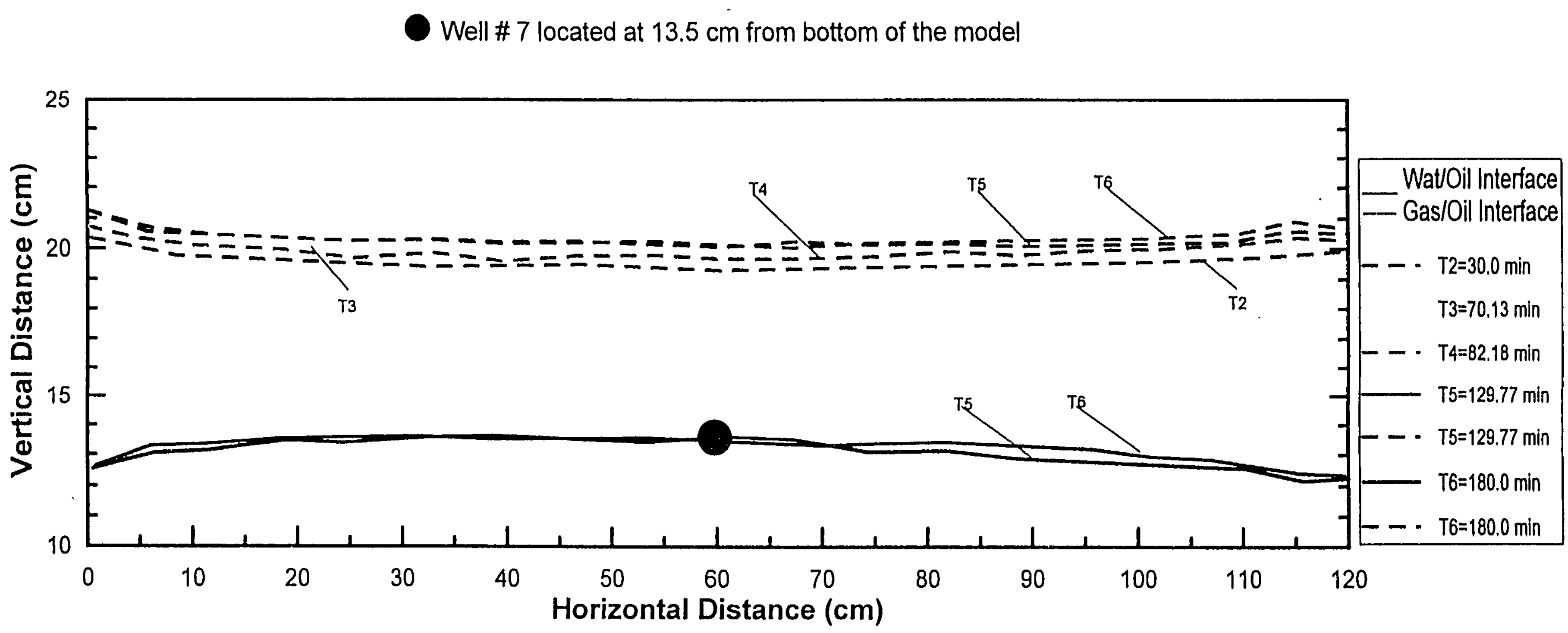

Figure 5.72(b): Enlarged vertical section of interface movement for SWGD at 1cc/min

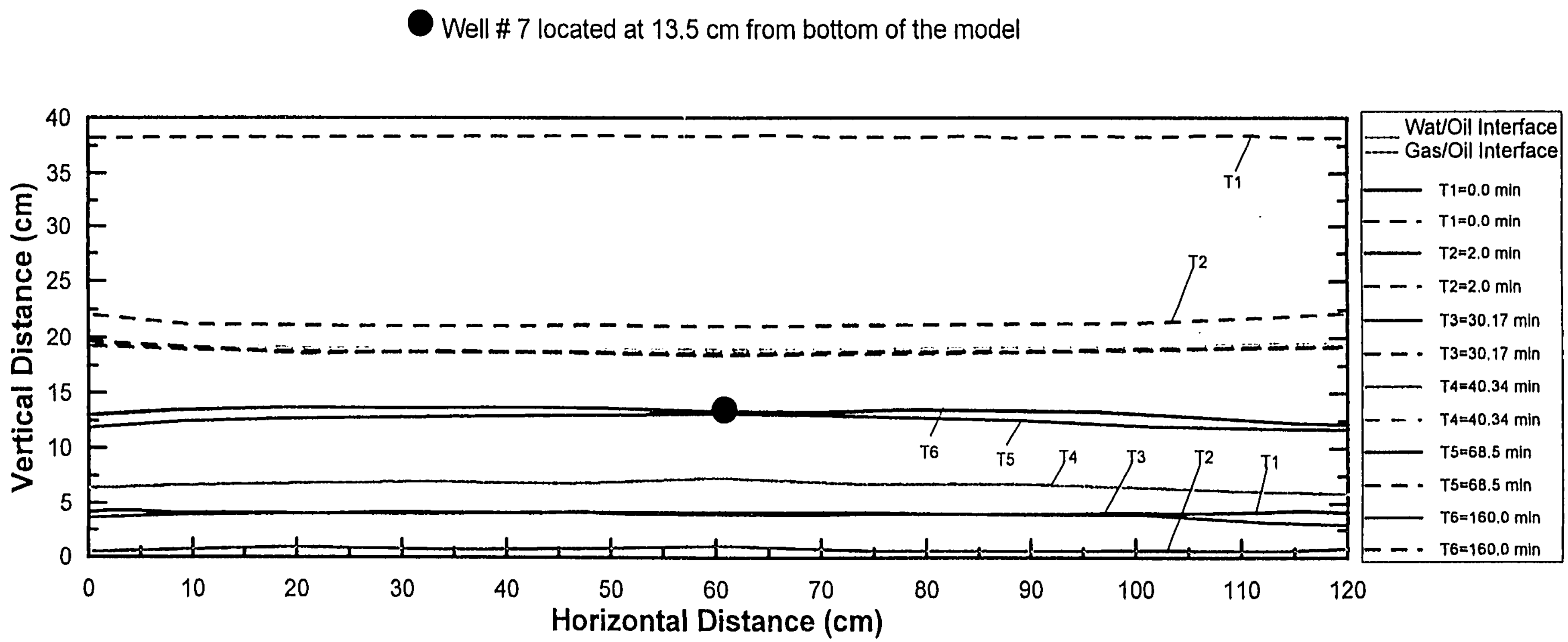

Figure 5.73(a): Interface movement for SWGD at 2cc/min from well # 7

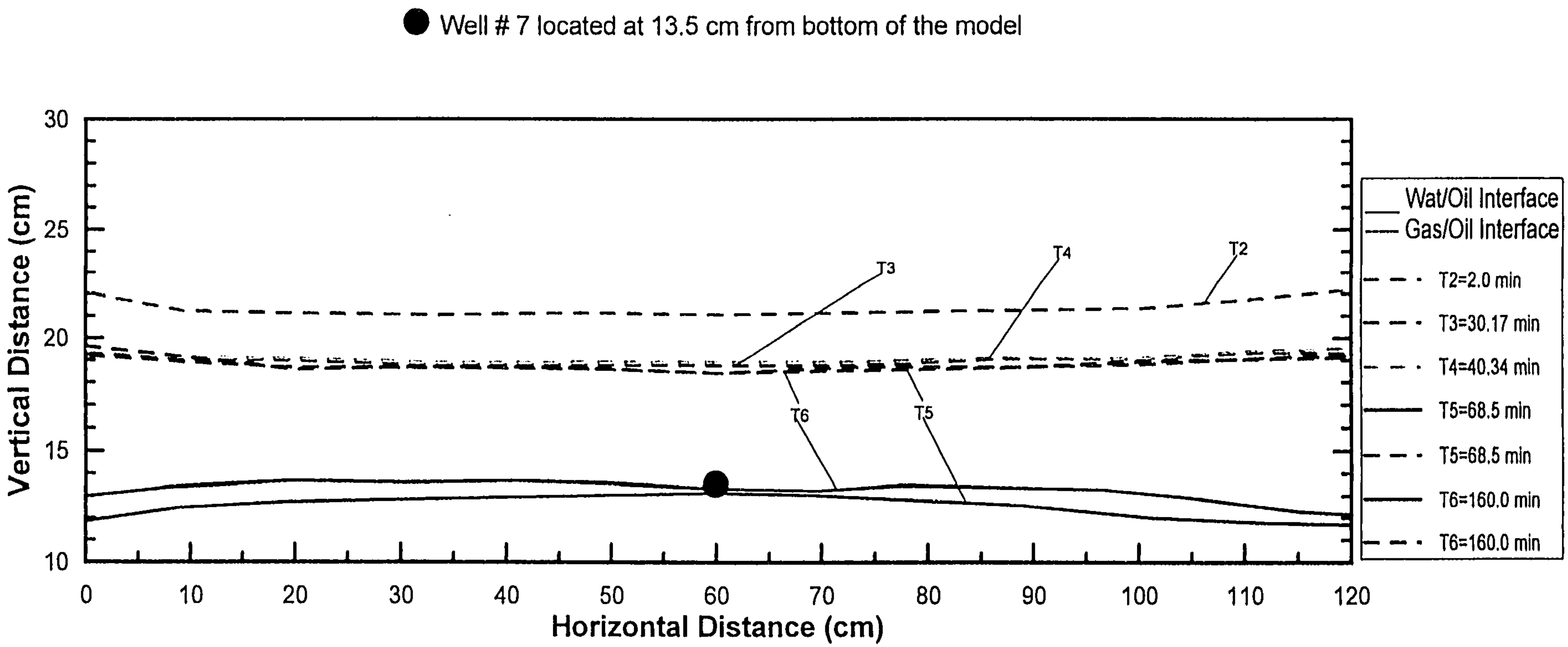

Figure 5.73(b) : Enlarged vertical section of interface movement for SWGD at 2cc/min

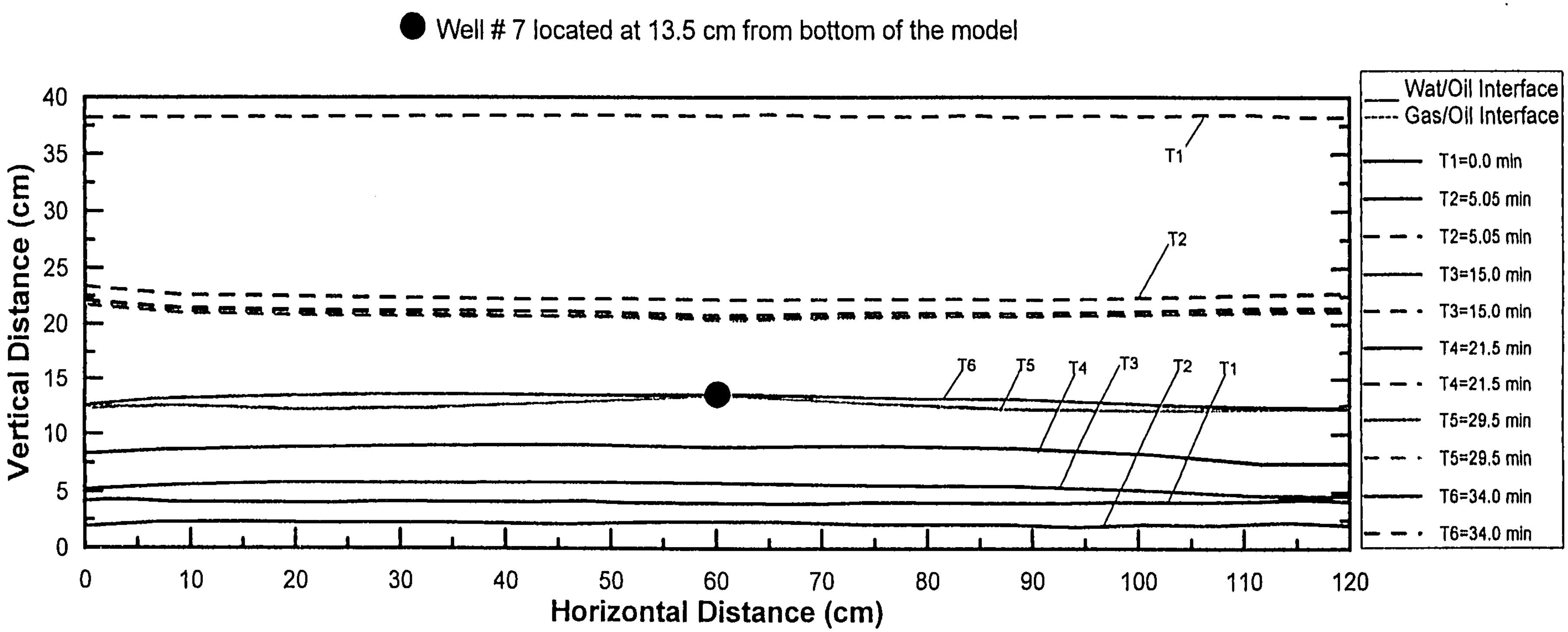

Figure 5.74(a): Interface movement for SWGD at 4cc/min from well # 7

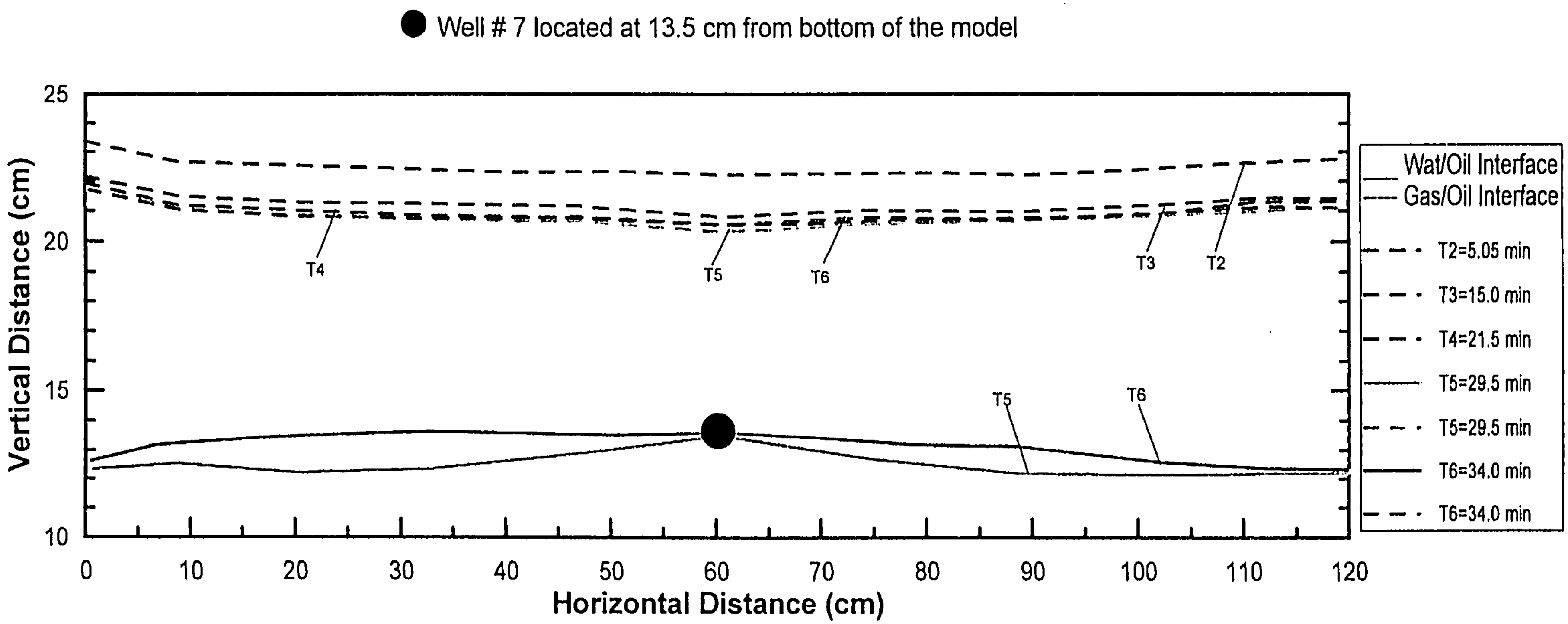

Figure 5.74(b): Enlarged vertical section of interface movement for SWGD at 4cc/min

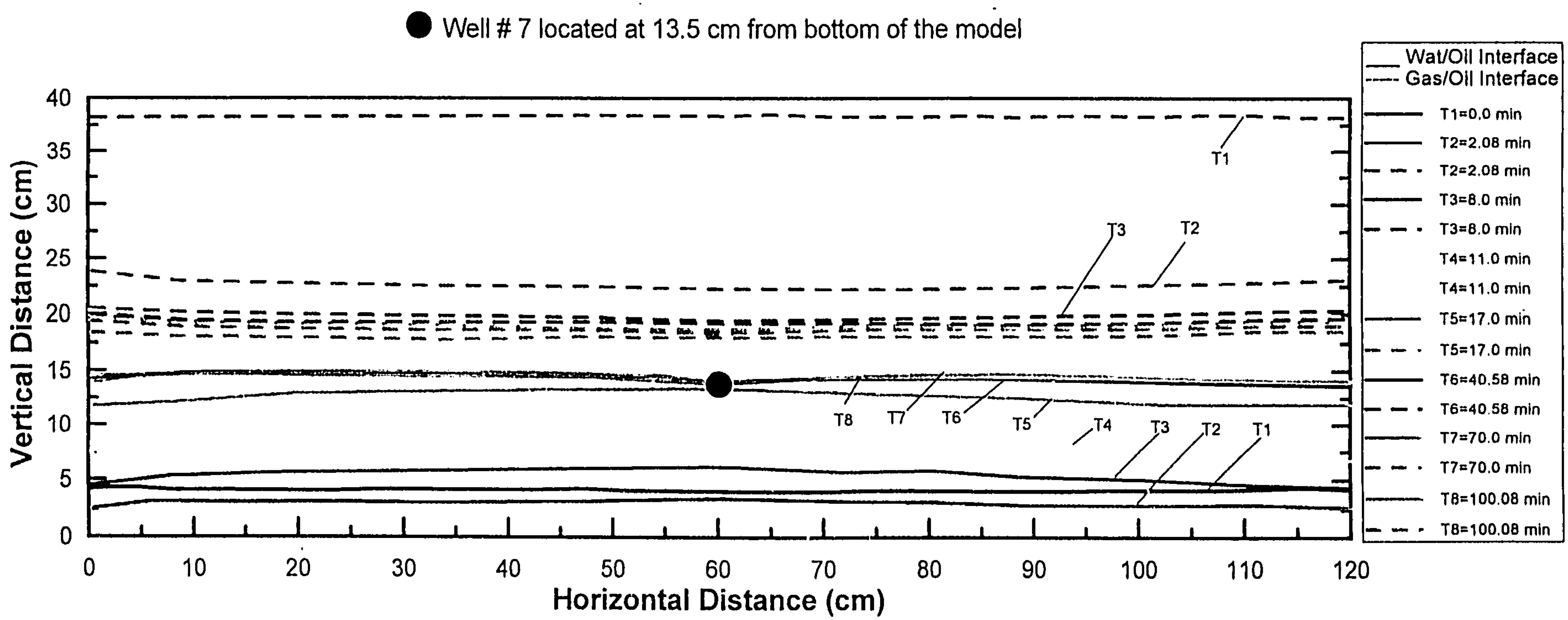

Figure 5.75(a): Interface movement for SWGD at 7.6cc/min from well # 7

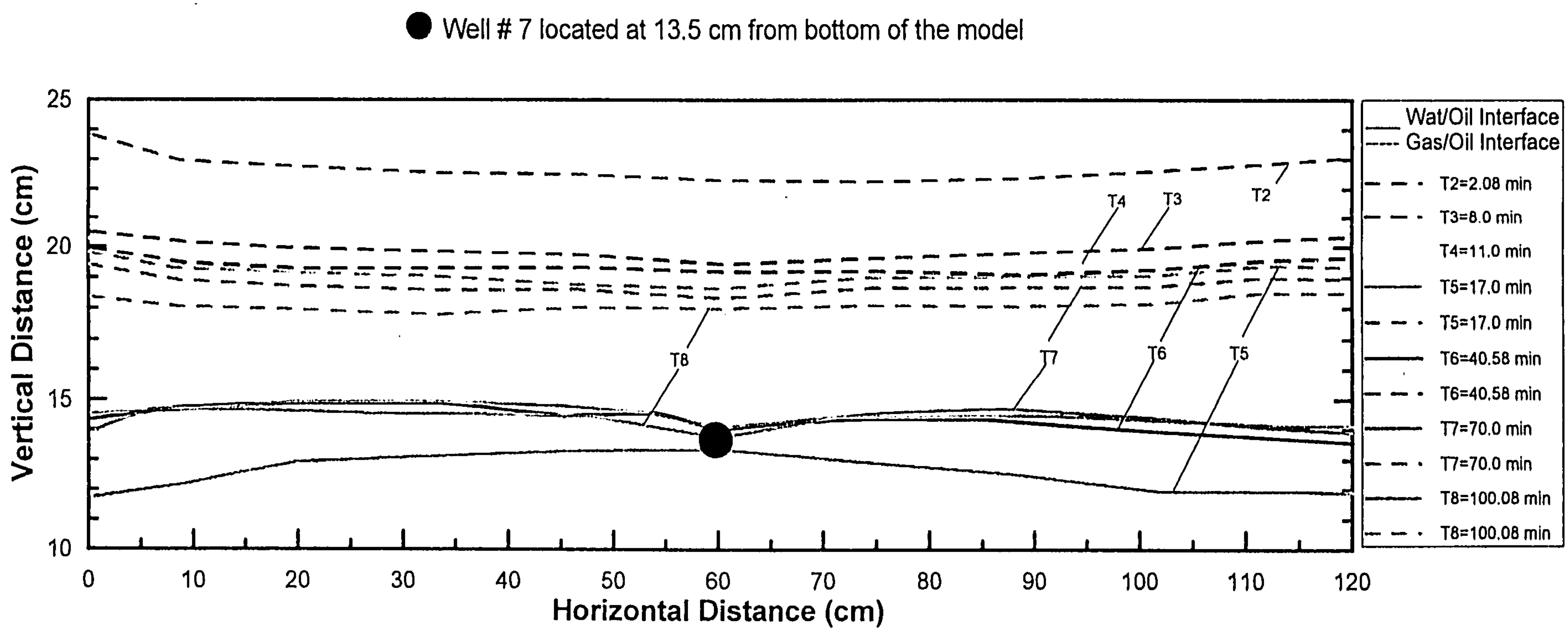

Figure 5.75(b): Enlarged vertical section of interface movement for SWGD at 7.6cc/min

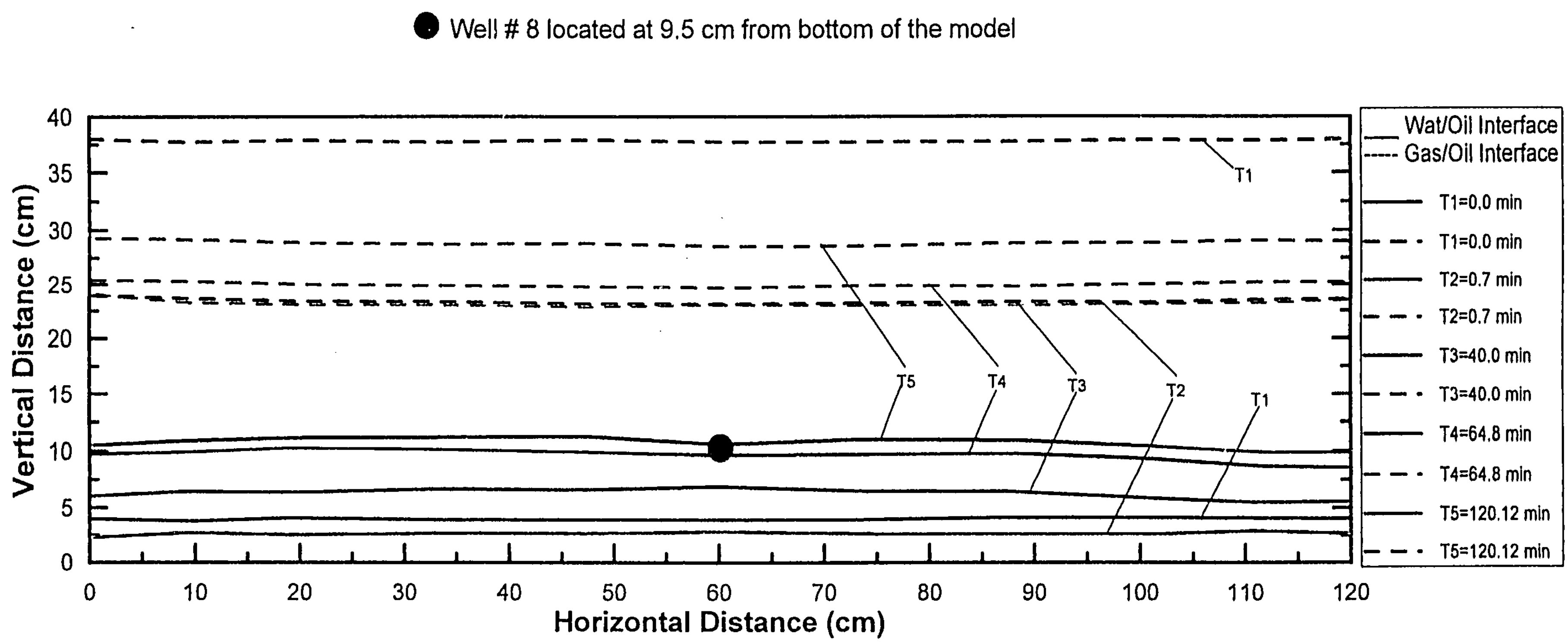

Figure 5.76(a): Interface movement for SWGD at 1cc/min from well # 8

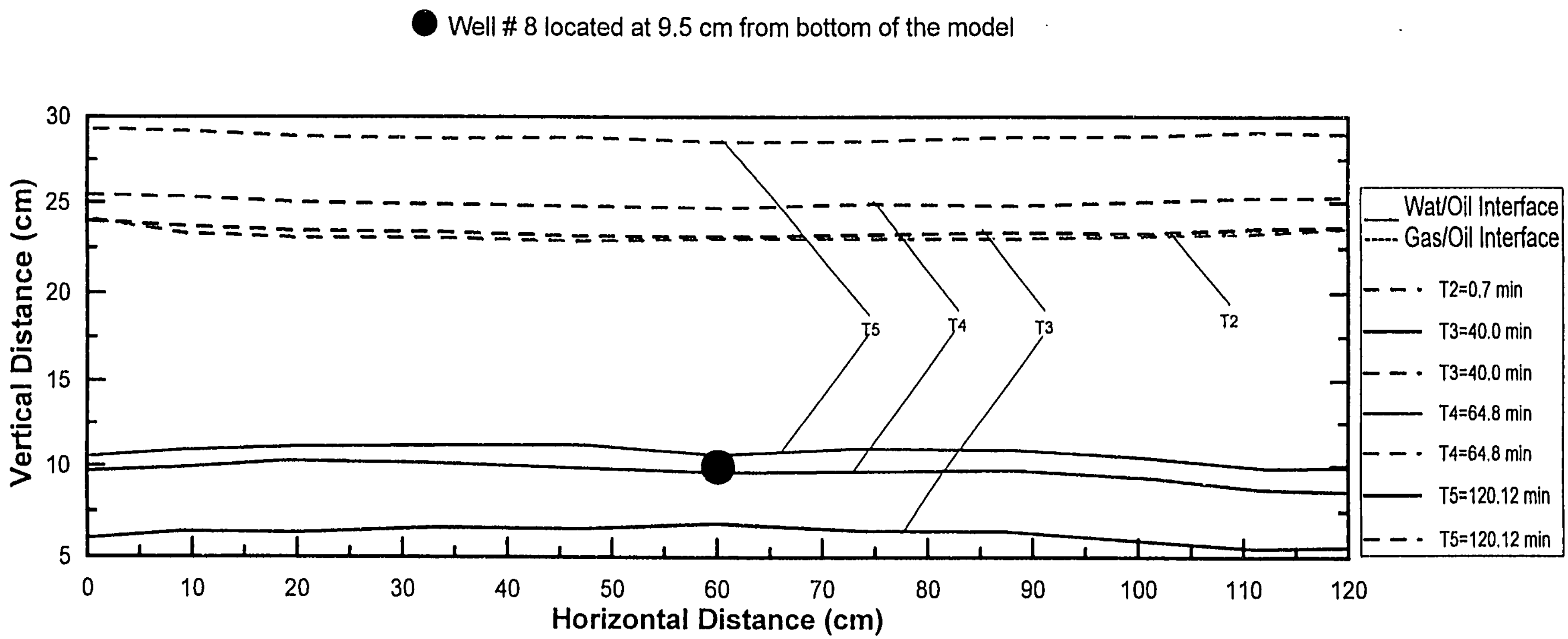

Figure 5.76(b): Enlarged vertical section of Interface movement for SWGD at 1cc/min

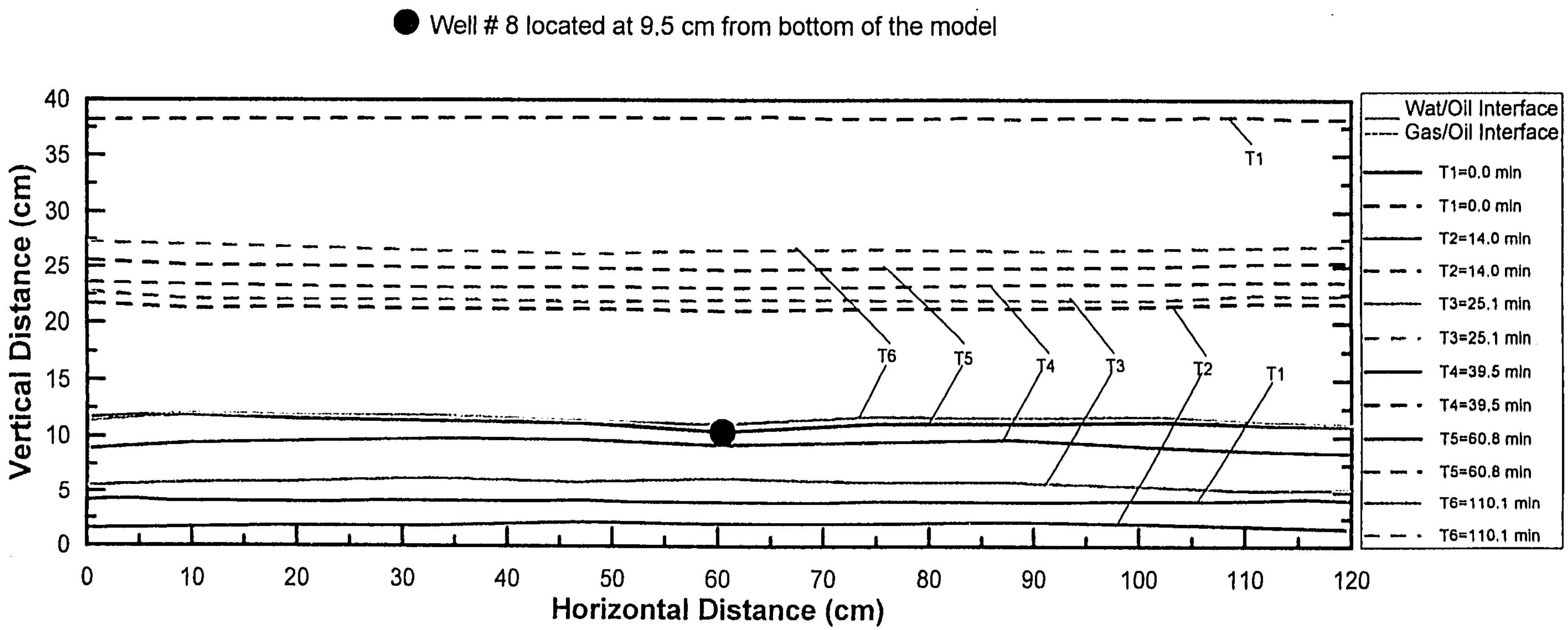

Figure 5.77(a): Interface movement for SWGD at 2cc/min from Well # 8

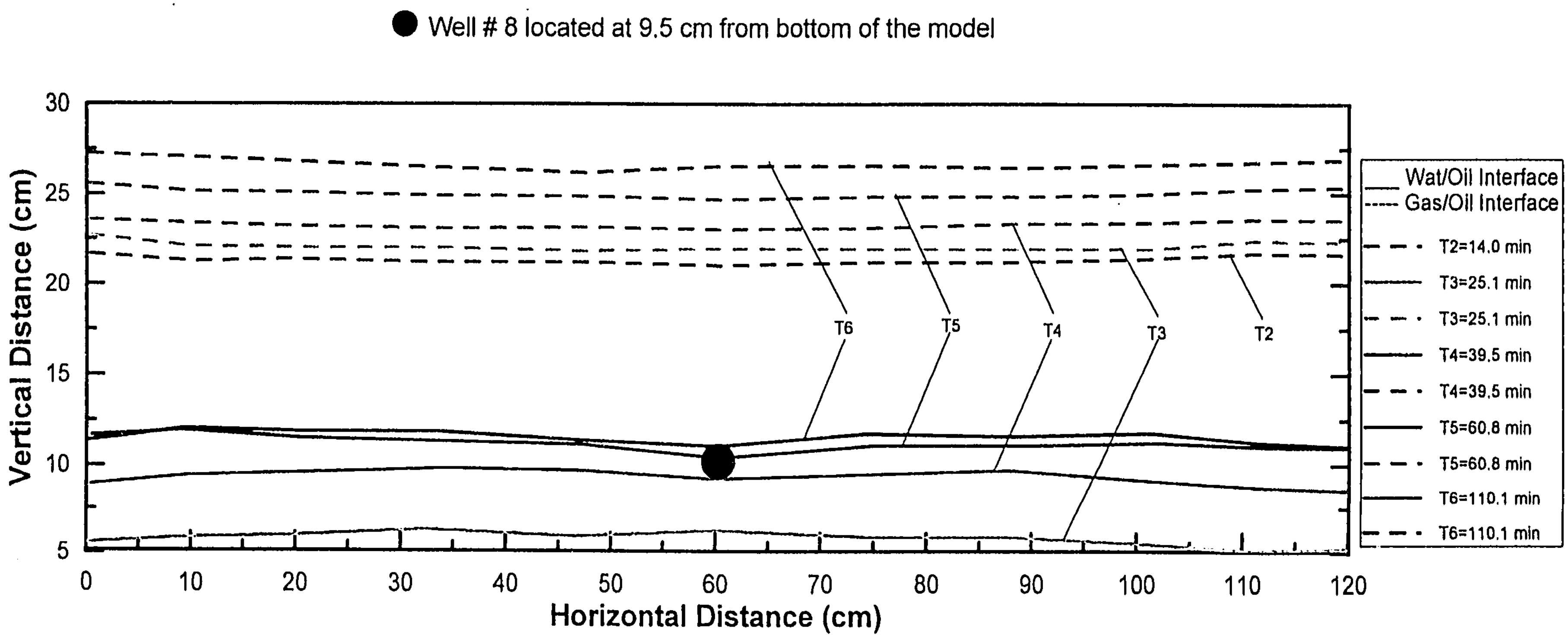

Figure 5.77(b): Enlarged vertical section of interface movement for SWGD at 2cc/min

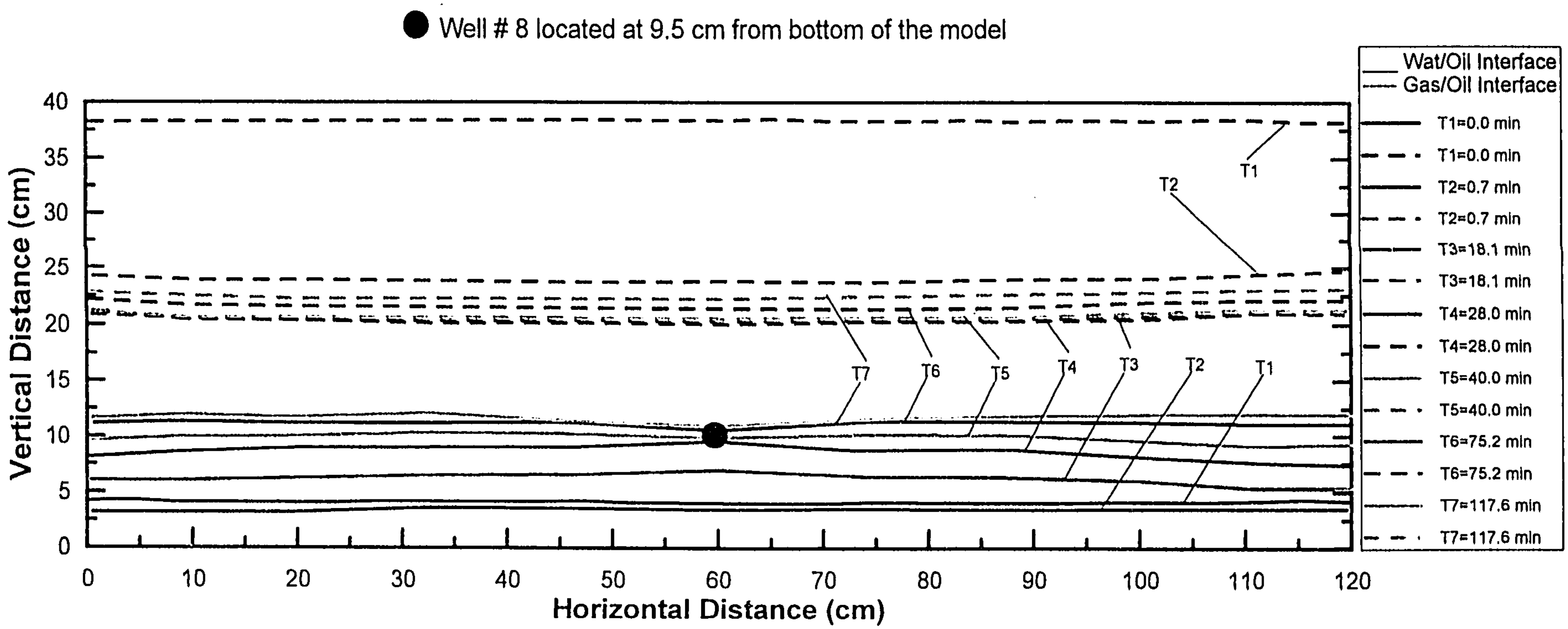

Figure 5.78(a): Interface movement for SWGD at 4cc/min from well # 8

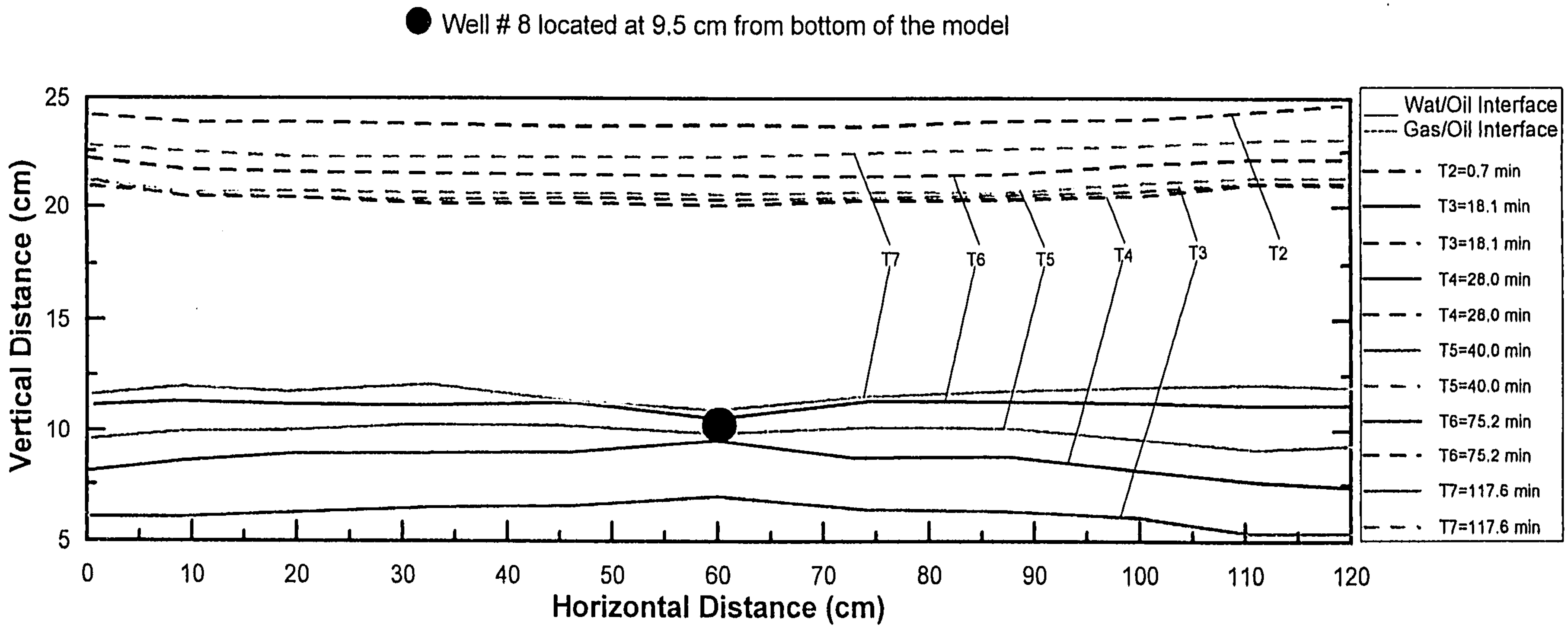

Figure 5.78(b): Enlarged vertical section of interface movement for SWGD at 4cc/min

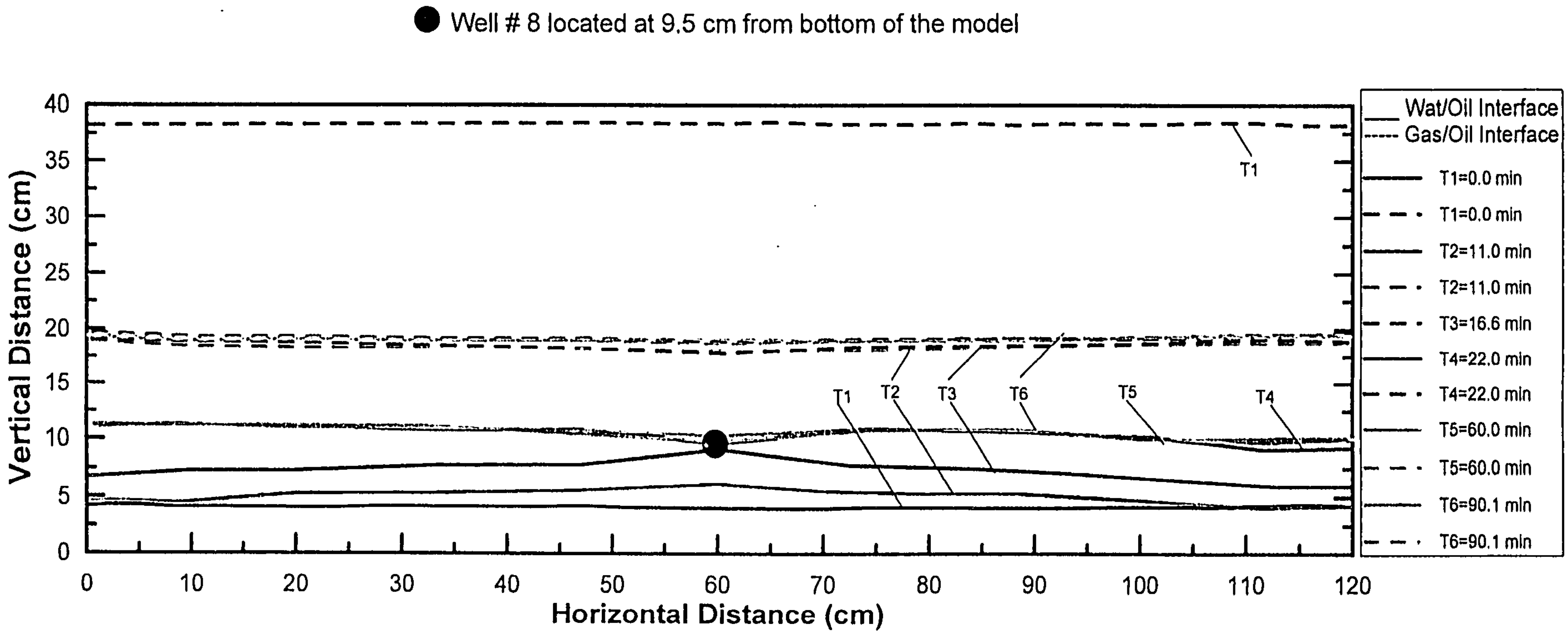

Figure 5.79(a): Interface movement for SWGD at 7.6cc/min from well # 8

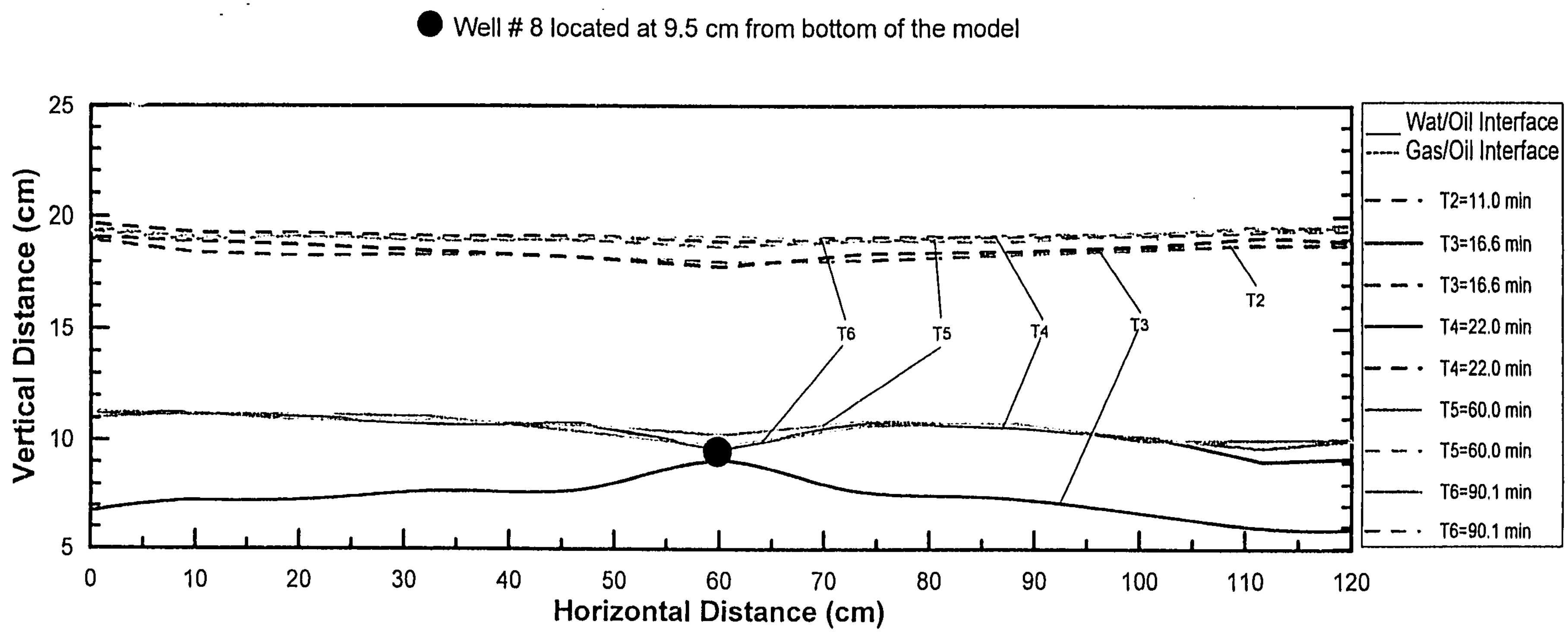

Figure 5.79(b): Enlarged vertical section of interface movement for SWGD at 7.6cc/min

water/oil interface moves upward displacing the oil and also pushing the gas/oil interface slowly back. The interfaces approach the production well more quickly at the higher production rates. No significant gas cone was observed even at the highest rate considered i.e. 7.6 cc/min. Water/oil interface did develop a cone when it reached near the well for higher rates. Instantaneous coning with multiple gas fingering is observed for very high rates. So it is better to recover more oil in a lesser time provided that a significant cone is avoided.

Chapter 6

CONCLUSIONS

An experimental study has been conducted to investigate the production performance of horizontal wells under a bottom-water drive, a gas-cap drive and a simultaneous bottom-water and gas-cap drive. The study was conducted using a Hele-Shaw model of dimensions 120 cm by 40 cm. The fluids used included oil (density = 0.83 gm/cc and viscosity = 4.6 cp) as the displaced fluid and, glycerol-water solution (density = 1.08 gm/cc and viscosity = 3.26 cp) and nitrogen gas as the displacing fluids. The model dimensions and the fluid properties have been determined from a previous scaling study to represent a real field in Saudi Arabia.

Based on the present results and analyses of the oil recovery, water-cut, breakthrough time, pressure drop and interface movement, the following conclusions are made:

1. For bottom-water drive, the oil recovery is higher and breakthrough time is longer for lower production rates, and for the well located farthest from the water/oil interface, that is, near the top of the reservoir. The recovery achieved at breakthrough was 87.2 % of original oil in place with a breakthrough time of 156 minutes at a production rate of 1 cc/min. At a production rate of 4.7 cc/min, these values were 72.4 % and 26.8 minutes, respectively. Also, the water/oil interface would become unstable as flow rate increases, giving rise to a significant water cone.

2. For gas-cap drive, oil recovery would be higher for higher production rates as long as no significant cone is developed. Breakthrough time would be lesser for higher rates. The optimal well location in this case would be near the bottom of the reservoir.

3. In the case of simultaneous bottom-water and gas-cap drive, oil recovery is higher for higher production rates if no prominent cone develops. The maximum recovery at breakthrough obtained for this scenario was 81.7 % of original oil in place at 7.6 cc/min with a breakthrough time of 18 minutes. At a production rate of 1 cc/min and for the same well location,

the recovery at breakthrough was 63.7 % and the breakthrough time was 118 minutes. The effective application of the gas-cap and the bottom-water at the same time would require not only to control the advance of the gas flow in such a manner that it does not finger through the oil and bypass it, but also to utilize the energy of the strong bottom-water drive to get the maximum recovery. This would be achieved at a production rate that is high enough to provide a high gas velocity which can displace most of the oil ahead of the gas/oil interface without actually destabilizing it and at the same time let the approaching water front to give a good sweep of the oil in front of it. At too high a rate, the interface stability is expected to be disturbed giving rise to a single or multiple gas or water fingers through the oil instead of pushing it in front of it and displacing it efficiently.

4. For simultaneous bottom-water and gas-cap drive, the well should be located closer to the water/oil interface as compared to the gas/oil interface, for recovering more oil. In the present study, the best well location under these conditions was found to be in a ratio of 1:1.5 between the water/oil and the gas/oil interface. The breakthrough time would be lower for such conditions, and therefore more oil would be recovered in lesser time.

Recommendation

The results show that if the reservoir has a strong water influx with a gas-cap at the top, it would be advantageous to have a gas-cap pressure that can retard the water encroaching the reservoir. In the present study, the gas-cap pressure was not being maintained by gas re-injection and the gas-cap pressure was depleted over time. Therefore, oil recovery can be improved in this regard by using gas re-injection into the gas-cap and maintaining its pressure. Further, investigation is needed to study this option.

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Appendix

The scaled values for the model dimensions and the fluid properties along with the actual reservoir values are presented below in Table A-1. The production data obtained from the experiments follows next in this appendix as a series of tables (Table A-2 to Table A-19). The original oil in place (OOIP) for BWD and SWGD is 173 cc and for GCD it is 150 cc.

Table A-1

Parameter	Reservoir	Model
Length (m)	1000	0.12
Oil Column Height (m)	112	0.34-0.36
Permeability (D)	3.75	13333
Oil Viscosity (cp)	0.82	4.6
Water Viscosity (cp)	0.58	3.26
Oil Density (gm/cc)	0.86	0.83
Water Density (gm/cc)	1.12	1.08

Table A-2

Production Data for Bottom Water Drive At 1cc/min For Well # 1											
Tube No.	Time/tube (min)	Cum Time(min)	Pore Vol Inj	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Cum Tot. Vol (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	6.00	6.00	0.03584	6.20	6.20	0.00	0.00	6.20	6.20	3.58	0.00
2	6.00	12.00	0.07168	6.20	12.40	0.00	0.00	6.20	12.40	7.17	0.00
3	6.00	18.00	0.10694	6.10	18.50	0.00	0.00	6.10	18.50	10.69	0.00
4	6.00	24.00	0.14162	6.00	24.50	0.00	0.00	6.00	24.50	14.16	0.00
5	6.00	30.00	0.17572	5.90	30.40	0.00	0.00	5.90	30.40	17.57	0.00
6	6.00	36.00	0.20983	5.90	36.30	0.00	0.00	5.90	36.30	20.98	0.00
7	6.00	42.00	0.24451	6.00	42.30	0.00	0.00	6.00	42.30	24.45	0.00
8	6.00	48.00	0.27803	5.80	48.10	0.00	0.00	5.80	48.10	27.80	0.00
9	6.00	54.00	0.31214	5.90	54.00	0.00	0.00	5.90	54.00	31.21	0.00
10	6.00	60.00	0.34624	5.90	59.90	0.00	0.00	5.90	59.90	34.62	0.00
11	6.00	66.00	0.37977	5.80	65.70	0.00	0.00	5.80	65.70	37.98	0.00
12	6.00	72.00	0.41329	5.80	71.50	0.00	0.00	5.80	71.50	41.33	0.00
13	6.00	78.00	0.44682	5.80	77.30	0.00	0.00	5.80	77.30	44.68	0.00
14	6.00	84.00	0.47977	5.70	83.00	0.00	0.00	5.70	83.00	47.98	0.00
15	6.00	90.00	0.51329	5.80	88.80	0.00	0.00	5.80	88.80	51.33	0.00
16	6.00	96.00	0.54624	5.70	94.50	0.00	0.00	5.70	94.50	54.62	0.00
17	6.00	102.00	0.57977	5.80	100.30	0.00	0.00	5.80	100.30	57.98	0.00
18	6.00	108.00	0.61329	5.80	106.10	0.00	0.00	5.80	106.10	61.33	0.00
19	6.00	114.00	0.64624	5.70	111.80	0.00	0.00	5.70	111.80	64.62	0.00
20	6.00	120.00	0.67977	5.80	117.60	0.00	0.00	5.80	117.60	67.98	0.00
21	6.00	126.00	0.71214	5.60	123.20	0.00	0.00	5.60	123.20	71.21	0.00
22	6.00	132.00	0.74451	5.60	128.80	0.00	0.00	5.60	128.80	74.45	0.00
23	6.00	138.00	0.77746	5.70	134.50	0.00	0.00	5.70	134.50	77.75	0.00
24	6.00	144.00	0.80925	5.50	140.00	0.00	0.00	5.50	140.00	80.92	0.00
25	4.00	148.00	0.83121	3.80	143.80	0.00	0.00	3.80	143.80	83.12	0.00
26	4.00	152.00	0.85260	3.70	147.50	0.00	0.00	3.70	147.50	85.26	0.00
27	4.00	156.00	0.87225	3.30	150.80	0.10	0.10	3.40	150.90	87.17	2.94
28	4.00	160.00	0.89133	2.80	153.60	0.50	0.60	3.30	154.20	88.79	15.15
29	4.00	164.00	0.90578	1.80	155.40	0.70	1.30	2.50	156.70	89.83	28.00
30	4.00	168.00	0.91908	1.40	156.80	0.90	2.20	2.30	159.00	90.64	39.13
31	4.00	172.00	0.93121	1.10	157.90	1.00	3.20	2.10	161.10	91.27	47.62
32	4.00	176.00	0.94509	1.10	159.00	1.30	4.50	2.40	163.50	91.91	54.17
33	4.00	180.00	0.96821	1.00	160.00	3.00	7.50	4.00	167.50	92.49	75.00
34	4.00	184.00	0.99769	1.00	161.00	4.10	11.60	5.10	172.60	93.06	80.39
35	4.00	188.00	1.02775	1.00	162.00	4.20	15.80	5.20	177.80	93.64	80.77
36	4.00	192.00	1.05838	0.80	162.80	4.50	20.30	5.30	183.10	94.10	84.91
37	4.00	196.00	1.08844	0.70	163.50	4.50	24.80	5.20	188.30	94.51	86.54
38	4.00	200.00	1.11618	0.40	163.90	4.40	29.20	4.80	193.10	94.74	91.67
39	4.00	204.00	1.14451	0.40	164.30	4.50	33.70	4.90	198.00	94.97	91.84
40	4.00	208.00	1.17341	0.40	164.70	4.60	38.30	5.00	203.00	95.20	92.00
41	4.00	212.00	1.20347	0.40	165.10	4.80	43.10	5.20	208.20	95.43	92.31
42	4.00	216.00	1.23237	0.30	165.40	4.70	47.80	5.00	213.20	95.61	94.00
43	4.00	220.00	1.26069	0.20	165.60	4.70	52.50	4.90	218.10	95.72	95.92

Table A-2

Production Data for Bottom Water Drive At 1cc/min For Well # 1											
Tube No.	Time/tube (min)	Cum Time(min)	Pore Vol Inj	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Cum Tot. Vol (cc)	Rec (% OOIP)	Water Cut (%)
44	4.00	224.00	1.28902	0.10	165.70	4.80	57.30	4.90	223.00	95.78	97.96
45	4.00	228.00	1.31792	0.10	165.80	4.90	62.20	5.00	228.00	95.84	98.00
46	4.00	232.00	1.34509	0.10	165.90	4.60	66.80	4.70	232.70	95.90	97.87
47	4.00	236.00	1.37283	0.10	166.00	4.70	71.50	4.80	237.50	95.95	97.92
48	4.00	240.00	1.40000	0.10	166.10	4.60	76.10	4.70	242.20	96.01	97.87
	240.00			166.10		76.10		242.20			

Table A-3

Production Data for Bottom Water Drive At 1.7cc/min For Well # 1											
Tube No.	Time/tube (min)	Cum Time(min)	Pore Vol Inj	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Cum Tot Vol (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	3.00	3.00	0.01618	2.80	2.80	0.00	0.00	2.80	2.80	1.62	0.00
2	3.00	6.00	0.03642	3.50	6.30	0.00	0.00	3.50	6.30	3.64	0.00
3	3.00	9.00	0.05896	3.90	10.20	0.00	0.00	3.90	10.20	5.90	0.00
4	3.00	12.00	0.08266	4.10	14.30	0.00	0.00	4.10	14.30	8.27	0.00
5	3.00	15.00	0.10925	4.60	18.90	0.00	0.00	4.60	18.90	10.92	0.00
6	3.00	18.00	0.13642	4.70	23.60	0.00	0.00	4.70	23.60	13.64	0.00
7	3.00	21.00	0.16532	5.00	28.60	0.00	0.00	5.00	28.60	16.53	0.00
8	3.00	24.00	0.19480	5.10	33.70	0.00	0.00	5.10	33.70	19.48	0.00
9	3.00	27.00	0.22486	5.20	38.90	0.00	0.00	5.20	38.90	22.49	0.00
10	3.00	30.00	0.25549	5.30	44.20	0.00	0.00	5.30	44.20	25.55	0.00
11	3.00	33.00	0.28671	5.40	49.60	0.00	0.00	5.40	49.60	28.67	0.00
12	3.00	36.00	0.31792	5.40	55.00	0.00	0.00	5.40	55.00	31.79	0.00
13	3.00	39.00	0.34913	5.40	60.40	0.00	0.00	5.40	60.40	34.91	0.00
14	3.00	42.00	0.38092	5.50	65.90	0.00	0.00	5.50	65.90	38.09	0.00
15	3.00	45.00	0.41272	5.50	71.40	0.00	0.00	5.50	71.40	41.27	0.00
16	3.00	48.00	0.44451	5.50	76.90	0.00	0.00	5.50	76.90	44.45	0.00
17	3.00	51.00	0.47630	5.50	82.40	0.00	0.00	5.50	82.40	47.63	0.00
18	3.00	54.00	0.50809	5.50	87.90	0.00	0.00	5.50	87.90	50.81	0.00
19	3.00	57.00	0.53988	5.50	93.40	0.00	0.00	5.50	93.40	53.99	0.00
20	3.00	60.00	0.57168	5.50	98.90	0.00	0.00	5.50	98.90	57.17	0.00
21	3.00	63.00	0.60347	5.50	104.40	0.00	0.00	5.50	104.40	60.35	0.00
22	3.00	66.00	0.63526	5.50	109.90	0.00	0.00	5.50	109.90	63.53	0.00
23	3.00	69.00	0.66705	5.50	115.40	0.00	0.00	5.50	115.40	66.71	0.00
24	3.00	72.00	0.69884	5.50	120.90	0.00	0.00	5.50	120.90	69.88	0.00
25	3.00	75.00	0.73064	5.50	126.40	0.00	0.00	5.50	126.40	73.06	0.00
26	3.00	78.00	0.76185	5.40	131.80	0.00	0.00	5.40	131.80	76.18	0.00
27	2.00	80.00	0.78324	3.70	135.50	0.00	0.00	3.70	135.50	78.32	0.00
28	2.00	82.00	0.80462	3.70	139.20	0.00	0.00	3.70	139.20	80.46	0.00
29	2.00	84.00	0.82428	3.30	142.50	0.10	0.10	3.40	142.60	82.37	2.94
30	2.00	86.00	0.83931	2.30	144.80	0.30	0.40	2.60	145.20	83.70	11.54
31	2.00	88.00	0.85434	2.10	146.90	0.50	0.90	2.60	147.80	84.91	19.23
32	2.00	90.00	0.86821	1.70	148.60	0.70	1.60	2.40	150.20	85.90	29.17
33	2.00	92.00	0.88092	1.50	150.10	0.70	2.30	2.20	152.40	86.76	31.82
34	2.00	94.00	0.89364	1.40	151.50	0.80	3.10	2.20	154.60	87.57	36.36
35	2.00	96.00	0.90578	1.10	152.60	1.00	4.10	2.10	156.70	88.21	47.62
36	2.00	98.00	0.91908	0.90	153.50	1.40	5.50	2.30	159.00	88.73	60.87
37	2.00	100.00	0.93757	1.00	154.50	2.20	7.70	3.20	162.20	89.31	68.75
38	2.00	102.00	0.97572	1.10	155.60	5.50	13.20	6.60	168.80	89.94	83.33
39	2.00	104.00	1.01329	0.80	156.40	5.70	18.90	6.50	175.30	90.40	87.69
40	2.00	106.00	1.04682	0.70	157.10	5.10	24.00	5.80	181.10	90.81	87.93
41	2.00	108.00	1.07861	0.60	157.70	4.90	28.90	5.50	186.60	91.16	89.09
42	2.00	110.00	1.10867	0.60	158.30	4.60	33.50	5.20	191.80	91.50	88.46
43	2.00	112.00	1.13642	0.40	158.70	4.40	37.90	4.80	196.60	91.73	91.67

Table A-3

Production Data for Bottom Water Drive At 1.7cc/min For Well # 1											
Tube No.	Time/tube (min)	Cum Time(min)	Pore Vol Inj	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Cum Tot Vol (cc)	Rec (% OOIP)	Water Cut (%)
44	2.00	114.00	1.16358	0.40	159.10	4.30	42.20	4.70	201.30	91.97	91.49
45	2.00	116.00	1.18960	0.40	159.50	4.10	46.30	4.50	205.80	92.20	91.11
46	2.00	118.00	1.21503	0.30	159.80	4.10	50.40	4.40	210.20	92.37	93.18
47	2.00	120.00	1.24046	0.30	160.10	4.10	54.50	4.40	214.60	92.54	93.18
48	2.00	122.00	1.26474	0.30	160.40	3.90	58.40	4.20	218.80	92.72	92.86
49	2.00	124.00	1.28844	0.20	160.60	3.90	62.30	4.10	222.90	92.83	95.12
50	2.00	126.00	1.31214	0.20	160.80	3.90	66.20	4.10	227.00	92.95	95.12
51	2.00	128.00	1.33584	0.20	161.00	3.90	70.10	4.10	231.10	93.06	95.12
52	2.00	130.00	1.35896	0.20	161.20	3.80	73.90	4.00	235.10	93.18	95.00
53	2.00	132.00	1.38150	0.10	161.30	3.80	77.70	3.90	239.00	93.24	97.44
54	2.00	134.00	1.40405	0.10	161.40	3.80	81.50	3.90	242.90	93.29	97.44
55	2.00	136.00	1.42717	0.10	161.50	3.90	85.40	4.00	246.90	93.35	97.50
	136.00			161.50		85.40		246.90			

Table A-4

Production Data for Bottom Water Drive At 3cc/min For Well # 1											
Tube No.	Time/tube (min)	Cum Time(min)	Pore Vol Inj	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Cum Tot Vol (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.50	1.50	0.00578	1.00	1.00	0.00	0.00	1.00	1.00	0.58	0.00
2	1.50	3.00	0.01618	1.80	2.80	0.00	0.00	1.80	2.80	1.62	0.00
3	1.50	4.50	0.02948	2.30	5.10	0.00	0.00	2.30	5.10	2.95	0.00
4	1.50	6.00	0.04509	2.70	7.80	0.00	0.00	2.70	7.80	4.51	0.00
5	1.50	7.50	0.06243	3.00	10.80	0.00	0.00	3.00	10.80	6.24	0.00
6	1.50	9.00	0.08092	3.20	14.00	0.00	0.00	3.20	14.00	8.09	0.00
7	1.50	10.50	0.10173	3.60	17.60	0.00	0.00	3.60	17.60	10.17	0.00
8	1.50	12.00	0.12370	3.80	21.40	0.00	0.00	3.80	21.40	12.37	0.00
9	1.50	13.50	0.14624	3.90	25.30	0.00	0.00	3.90	25.30	14.62	0.00
10	1.50	15.00	0.17110	4.30	29.60	0.00	0.00	4.30	29.60	17.11	0.00
11	1.50	16.50	0.19653	4.40	34.00	0.00	0.00	4.40	34.00	19.65	0.00
12	1.50	18.00	0.22312	4.60	38.60	0.00	0.00	4.60	38.60	22.31	0.00
13	1.50	19.50	0.24971	4.60	43.20	0.00	0.00	4.60	43.20	24.97	0.00
14	1.50	21.00	0.27746	4.80	48.00	0.00	0.00	4.80	48.00	27.75	0.00
15	1.50	22.50	0.30636	5.00	53.00	0.00	0.00	5.00	53.00	30.64	0.00
16	1.50	24.00	0.33642	5.20	58.20	0.00	0.00	5.20	58.20	33.64	0.00
17	1.50	25.50	0.36705	5.30	63.50	0.00	0.00	5.30	63.50	36.71	0.00
18	1.50	27.00	0.39769	5.30	68.80	0.00	0.00	5.30	68.80	39.77	0.00
19	1.50	28.50	0.42890	5.40	74.20	0.00	0.00	5.40	74.20	42.89	0.00
20	1.50	30.00	0.46012	5.40	79.60	0.00	0.00	5.40	79.60	46.01	0.00
21	1.50	31.50	0.49133	5.40	85.00	0.00	0.00	5.40	85.00	49.13	0.00
22	1.50	33.00	0.52312	5.50	90.50	0.00	0.00	5.50	90.50	52.31	0.00
23	1.50	34.50	0.55491	5.50	96.00	0.00	0.00	5.50	96.00	55.49	0.00
24	1.50	36.00	0.58555	5.30	101.30	0.00	0.00	5.30	101.30	58.55	0.00
25	1.50	37.50	0.61676	5.40	106.70	0.00	0.00	5.40	106.70	61.68	0.00
26	1.50	39.00	0.64855	5.50	112.20	0.00	0.00	5.50	112.20	64.86	0.00
27	1.50	40.50	0.67977	5.40	117.60	0.00	0.00	5.40	117.60	67.98	0.00
28	1.50	42.00	0.71098	5.40	123.00	0.00	0.00	5.40	123.00	71.10	0.00
29	1.50	43.50	0.73237	3.70	126.70	0.00	0.00	3.70	126.70	73.24	0.00
30	1.00	44.50	0.75318	3.60	130.30	0.00	0.00	3.60	130.30	75.32	0.00
31	1.00	45.50	0.77399	3.50	133.80	0.10	0.10	3.60	133.90	77.34	2.78
32	1.00	46.50	0.79249	2.90	136.70	0.30	0.40	3.20	137.10	79.02	9.38
33	1.00	47.50	0.80983	2.40	139.10	0.60	1.00	3.00	140.10	80.40	20.00
34	1.00	48.50	0.82486	1.90	141.00	0.70	1.70	2.60	142.70	81.50	26.92
35	1.00	49.50	0.83931	1.70	142.70	0.80	2.50	2.50	145.20	82.49	32.00
36	1.00	50.50	0.85318	1.50	144.20	0.90	3.40	2.40	147.60	83.35	37.50
37	1.00	51.50	0.86705	1.40	145.60	1.00	4.40	2.40	150.00	84.16	41.67
38	1.00	52.50	0.88035	1.30	146.90	1.00	5.40	2.30	152.30	84.91	43.48
39	1.00	53.50	0.89422	1.10	148.00	1.30	6.70	2.40	154.70	85.55	54.17
40	1.00	54.50	0.90867	1.10	149.10	1.40	8.10	2.50	157.20	86.18	56.00
41	1.00	55.50	0.92775	1.20	150.30	2.10	10.20	3.30	160.50	86.88	63.64
42	1.00	56.50	0.95202	1.10	151.40	3.10	13.30	4.20	164.70	87.51	73.81
43	1.00	57.50	0.98613	1.10	152.50	4.80	18.10	5.90	170.60	88.15	81.36

Table A-4

Production Data for Bottom Water Drive At 3cc/min For Well # 1

Tube No.	Time/tube (min)	Cum Time(min)	Pore Vol Inj	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Cum Tot Vol (cc)	Rec (% OOIP)	Water Cut (%)
44	1.00	58.50	1.01965	0.90	153.40	4.90	23.00	5.80	176.40	88.67	84.48
45	1.00	59.50	1.05260	0.80	154.20	4.90	27.90	5.70	182.10	89.13	85.96
46	1.00	60.50	1.08382	0.70	154.90	4.70	32.60	5.40	187.50	89.54	87.04
47	1.00	61.50	1.11387	0.60	155.50	4.60	37.20	5.20	192.70	89.88	88.46
48	1.00	62.50	1.14335	0.50	156.00	4.60	41.80	5.10	197.80	90.17	90.20
49	1.00	63.50	1.17225	0.40	156.40	4.60	46.40	5.00	202.80	90.40	92.00
50	1.00	64.50	1.20058	0.40	156.80	4.50	50.90	4.90	207.70	90.64	91.84
51	1.00	65.50	1.22832	0.40	157.20	4.40	55.30	4.80	212.50	90.87	91.67
52	1.00	66.50	1.25434	0.40	157.60	4.10	59.40	4.50	217.00	91.10	91.11
53	1.00	67.50	1.28092	0.40	158.00	4.20	63.60	4.60	221.60	91.33	91.30
54	1.00	68.50	1.30694	0.30	158.30	4.20	67.80	4.50	226.10	91.50	93.33
55	1.00	69.50	1.33295	0.30	158.60	4.20	72.00	4.50	230.60	91.68	93.33
56	1.00	70.50	1.35896	0.30	158.90	4.20	76.20	4.50	235.10	91.85	93.33
57	1.00	71.50	1.38382	0.30	159.20	4.00	80.20	4.30	239.40	92.02	93.02
58	1.00	72.50	1.40867	0.20	159.40	4.10	84.30	4.30	243.70	92.14	95.35
59	1.00	73.50	1.43353	0.20	159.60	4.10	88.40	4.30	248.00	92.25	95.35
60	1.00	74.50	1.45780	0.20	159.80	4.00	92.40	4.20	252.20	92.37	95.24
61	1.00	75.50	1.48150	0.10	159.90	4.00	96.40	4.10	256.30	92.43	97.56
62	1.00	76.50	1.50578	0.10	160.00	4.10	100.50	4.20	260.50	92.49	97.62
63	1.00	77.50	1.52890	0.10	160.10	3.90	104.40	4.00	264.50	92.54	97.50
64	1.00	78.50	1.55202	0.10	160.20	3.90	108.30	4.00	268.50	92.60	97.50
65	1.00	79.50	1.57572	0.10	160.30	4.00	112.30	4.10	272.60	92.66	97.56
66	1.00	80.50	1.60000	0.10	160.40	4.10	116.40	4.20	276.80	92.72	97.62
67	1.00	81.50	1.62428	0.10	160.50	4.10	120.50	4.20	281.00	92.77	97.62
68	1.00	82.50	1.64855	0.10	160.60	4.10	124.60	4.20	285.20	92.83	97.62
69	1.00	83.50	1.67283	0.10	160.70	4.10	128.70	4.20	289.40	92.89	97.62
70	1.00	84.50	1.69653	0.10	160.80	4.00	132.70	4.10	293.50	92.95	97.56
71	1.00	85.50	1.72023	0.10	160.90	4.00	136.70	4.10	297.60	93.01	97.56
	85.50			160.90		136.70		297.60			

Table A-5

Production Data for Bottom Water Drive At 4.7cc/min For Well # 1											
Tube No.	Time/tube (min)	Cum Time(min)	Pore Vol Inj	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Cum Tot Vol (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.00	1.00	0.00925	1.60	1.60	0.00	0.00	1.60	1.60	0.92	0.00
2	1.00	2.00	0.02023	1.90	3.50	0.00	0.00	1.90	3.50	2.02	0.00
3	1.00	3.00	0.03064	1.80	5.30	0.00	0.00	1.80	5.30	3.06	0.00
4	1.00	4.00	0.04566	2.60	7.90	0.00	0.00	2.60	7.90	4.57	0.00
5	1.00	5.00	0.06301	3.00	10.90	0.00	0.00	3.00	10.90	6.30	0.00
6	1.00	6.00	0.08208	3.30	14.20	0.00	0.00	3.30	14.20	8.21	0.00
7	1.00	7.00	0.10347	3.70	17.90	0.00	0.00	3.70	17.90	10.35	0.00
8	1.00	8.00	0.12601	3.90	21.80	0.00	0.00	3.90	21.80	12.60	0.00
9	1.00	9.00	0.15029	4.20	26.00	0.00	0.00	4.20	26.00	15.03	0.00
10	1.00	10.00	0.17572	4.40	30.40	0.00	0.00	4.40	30.40	17.57	0.00
11	1.00	11.00	0.20231	4.60	35.00	0.00	0.00	4.60	35.00	20.23	0.00
12	1.00	12.00	0.22948	4.70	39.70	0.00	0.00	4.70	39.70	22.95	0.00
13	1.00	13.00	0.25838	5.00	44.70	0.00	0.00	5.00	44.70	25.84	0.00
14	1.00	14.00	0.28844	5.20	49.90	0.00	0.00	5.20	49.90	28.84	0.00
15	1.00	15.00	0.31908	5.30	55.20	0.00	0.00	5.30	55.20	31.91	0.00
16	1.00	16.00	0.35087	5.50	60.70	0.00	0.00	5.50	60.70	35.09	0.00
17	1.00	17.00	0.38324	5.60	66.30	0.00	0.00	5.60	66.30	38.32	0.00
18	1.00	18.00	0.41676	5.80	72.10	0.00	0.00	5.80	72.10	41.68	0.00
19	1.00	19.00	0.45029	5.80	77.90	0.00	0.00	5.80	77.90	45.03	0.00
20	1.00	20.00	0.48382	5.80	83.70	0.00	0.00	5.80	83.70	48.38	0.00
21	1.00	21.00	0.51850	6.00	89.70	0.00	0.00	6.00	89.70	51.85	0.00
22	1.00	22.00	0.55376	6.10	95.80	0.00	0.00	6.10	95.80	55.38	0.00
23	1.00	23.00	0.58960	6.20	102.00	0.00	0.00	6.20	102.00	58.96	0.00
24	1.00	24.00	0.62486	6.10	108.10	0.00	0.00	6.10	108.10	62.49	0.00
25	1.00	25.00	0.66069	6.20	114.30	0.00	0.00	6.20	114.30	66.07	0.00
26	0.50	25.50	0.68092	3.50	117.80	0.00	0.00	3.50	117.80	68.09	0.00
27	0.50	26.00	0.69827	3.00	120.80	0.00	0.00	3.00	120.80	69.83	0.00
28	0.50	26.50	0.71156	2.30	123.10	0.00	0.00	2.30	123.10	71.16	0.00
29	0.50	27.00	0.72486	2.10	125.20	0.20	0.20	2.30	125.40	72.37	8.70
30	0.50	27.50	0.73699	1.80	127.00	0.30	0.50	2.10	127.50	73.41	14.29
31	0.50	28.00	0.75145	1.70	128.70	0.80	1.30	2.50	130.00	74.39	32.00
32	0.50	28.50	0.76532	1.50	130.20	0.90	2.20	2.40	132.40	75.26	37.50
33	0.50	29.00	0.77919	1.40	131.60	1.00	3.20	2.40	134.80	76.07	41.67
34	0.50	29.50	0.79306	1.30	132.90	1.10	4.30	2.40	137.20	76.82	45.83
35	0.50	30.00	0.80694	1.20	134.10	1.20	5.50	2.40	139.60	77.51	50.00
36	0.50	30.50	0.82081	1.10	135.20	1.30	6.80	2.40	142.00	78.15	54.17
37	0.50	31.00	0.83699	1.20	136.40	1.60	8.40	2.80	144.80	78.84	57.14
38	0.50	31.50	0.85434	1.00	137.40	2.00	10.40	3.00	147.80	79.42	66.67
39	0.50	32.00	0.87803	1.00	138.40	3.10	13.50	4.10	151.90	80.00	75.61
40	0.50	32.50	0.90405	1.10	139.50	3.40	16.90	4.50	156.40	80.64	75.56
41	0.50	33.00	0.92948	0.70	140.20	3.70	20.60	4.40	160.80	81.04	84.09
42	0.50	33.50	0.95434	0.70	140.90	3.60	24.20	4.30	165.10	81.45	83.72
43	0.50	34.00	0.98035	0.80	141.70	3.70	27.90	4.50	169.60	81.91	82.22

Table A-5

Production Data for Bottom Water Drive At 4.7cc/min For Well # 1											
Tube No.	Time/tube (min)	Cum Time(min)	Pore Vol Inj	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Cum Tot Vol (cc)	Rec (% OOIP)	Water Cut (%)
44	0.50	34.50	1.00636	0.70	142.40	3.80	31.70	4.50	174.10	82.31	84.44
45	0.50	35.00	1.03237	0.70	143.10	3.80	35.50	4.50	178.60	82.72	84.44
46	0.50	35.50	1.05780	0.60	143.70	3.80	39.30	4.40	183.00	83.06	86.36
47	0.50	36.00	1.08324	0.60	144.30	3.80	43.10	4.40	187.40	83.41	86.36
48	0.50	36.50	1.10867	0.60	144.90	3.80	46.90	4.40	191.80	83.76	86.36
49	0.50	37.00	1.13353	0.50	145.40	3.80	50.70	4.30	196.10	84.05	88.37
50	0.50	37.50	1.15780	0.50	145.90	3.70	54.40	4.20	200.30	84.34	88.10
51	0.50	38.00	1.18208	0.50	146.40	3.70	58.10	4.20	204.50	84.62	88.10
52	0.50	38.50	1.20694	0.40	146.80	3.90	62.00	4.30	208.80	84.86	90.70
53	0.50	39.00	1.23179	0.40	147.20	3.90	65.90	4.30	213.10	85.09	90.70
54	0.50	39.50	1.25607	0.30	147.50	3.90	69.80	4.20	217.30	85.26	92.86
55	0.50	40.00	1.28035	0.30	147.80	3.90	73.70	4.20	221.50	85.43	92.86
56	0.50	40.50	1.30405	0.30	148.10	3.80	77.50	4.10	225.60	85.61	92.68
57	0.50	41.00	1.32717	0.30	148.40	3.70	81.20	4.00	229.60	85.78	92.50
58	0.50	41.50	1.34971	0.30	148.70	3.60	84.80	3.90	233.50	85.95	92.31
59	0.50	42.00	1.37225	0.30	149.00	3.60	88.40	3.90	237.40	86.13	92.31
60	0.50	42.50	1.39538	0.30	149.30	3.70	92.10	4.00	241.40	86.30	92.50
61	0.50	43.00	1.41792	0.30	149.60	3.60	95.70	3.90	245.30	86.47	92.31
62	0.50	43.50	1.44104	0.30	149.90	3.70	99.40	4.00	249.30	86.65	92.50
63	0.50	44.00	1.46358	0.30	150.20	3.60	103.00	3.90	253.20	86.82	92.31
64	0.50	44.50	1.48671	0.30	150.50	3.70	106.70	4.00	257.20	86.99	92.50
65	0.50	45.00	1.50867	0.20	150.70	3.60	110.30	3.80	261.00	87.11	94.74
66	0.50	45.50	1.53121	0.30	151.00	3.60	113.90	3.90	264.90	87.28	92.31
67	0.50	46.00	1.55376	0.20	151.20	3.70	117.60	3.90	268.80	87.40	94.87
68	0.50	46.50	1.57630	0.20	151.40	3.70	121.30	3.90	272.70	87.51	94.87
69	0.50	47.00	1.59827	0.20	151.60	3.60	124.90	3.80	276.50	87.63	94.74
70	0.50	47.50	1.62023	0.20	151.80	3.60	128.50	3.80	280.30	87.75	94.74
71	0.50	48.00	1.64220	0.20	152.00	3.60	132.10	3.80	284.10	87.86	94.74
72	0.50	48.50	1.66474	0.20	152.20	3.70	135.80	3.90	288.00	87.98	94.87
73	0.50	49.00	1.68728	0.20	152.40	3.70	139.50	3.90	291.90	88.09	94.87
74	0.50	49.50	1.70867	0.10	152.50	3.60	143.10	3.70	295.60	88.15	97.30
75	0.50	50.00	1.73006	0.10	152.60	3.60	146.70	3.70	299.30	88.21	97.30
76	0.50	50.50	1.74624	0.10	152.70	2.70	149.40	2.80	302.10	88.27	96.43
	50.50			152.70		149.40		302.10			

Table A-6

Production Data for Gas Cap Drive At 2.6cc/min For Well # 8					
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Rec (% OOIP)
0	0.00	0.00	0.00	0.00	0.00
1	1.00	1.00	4.00	4.00	2.67
2	1.00	2.00	3.70	7.70	5.13
3	1.00	3.00	3.50	11.20	7.47
4	1.00	4.00	3.20	14.40	9.60
5	1.00	5.00	3.30	17.70	11.80
6	2.00	7.00	7.00	24.70	16.47
7	2.00	9.00	7.10	31.80	21.20
8	2.00	11.00	6.90	38.70	25.80
9	2.00	13.00	6.40	45.10	30.07
10	2.00	15.00	6.20	51.30	34.20
11	2.00	17.00	6.00	57.30	38.20
12	2.00	19.00	5.90	63.20	42.13
13	2.00	21.00	5.80	69.00	46.00
14	2.00	23.00	5.70	74.70	49.80
15	2.00	25.00	5.80	80.50	53.67
16	2.00	27.00	5.60	86.10	57.40
17	2.00	29.00	5.50	91.60	61.07
18	2.00	31.00	5.20	96.80	64.53
19	2.00	33.00	4.90	101.70	67.80
20	2.00	35.00	4.40	106.10	70.73
21	2.00	37.00	4.00	110.10	73.40
22	2.00	39.00	3.60	113.70	75.80
23	2.00	41.00	3.30	117.00	78.00
24	2.00	43.00	2.80	119.80	79.87
25	2.00	45.00	2.40	122.20	81.47
26	2.00	47.00	2.10	124.30	82.87
27	1.00	48.00	0.90	125.20	83.47
	48.00		125.20		

Table A-7

Production Data for Gas Cap Drive At 5.3cc/min For Well # 8					
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Rec (% OOIP)
0	0.00	0.00	0.00	0.00	0.00
1	1.00	1.00	8.00	8.00	5.33
2	1.00	2.00	7.00	15.00	10.00
3	1.00	3.00	7.10	22.10	14.73
4	1.00	4.00	7.00	29.10	19.40
5	1.00	5.00	6.90	36.00	24.00
6	1.00	6.00	7.00	43.00	28.67
7	1.00	7.00	6.50	49.50	33.00
8	1.00	8.00	6.40	55.90	37.27
9	1.00	9.00	6.00	61.90	41.27
10	1.00	10.00	5.80	67.70	45.13
11	1.00	11.00	5.20	72.90	48.60
12	1.00	12.00	5.10	78.00	52.00
13	1.00	13.00	5.00	83.00	55.33
14	1.00	14.00	5.00	88.00	58.67
15	1.00	15.00	4.90	92.90	61.93
16	1.00	16.00	4.70	97.60	65.07
17	1.00	17.00	4.50	102.10	68.07
18	1.00	18.00	4.60	106.70	71.13
19	1.00	19.00	4.10	110.80	73.87
20	1.00	20.00	4.00	114.80	76.53
21	1.00	21.00	3.50	118.30	78.87
22	1.00	22.00	3.60	121.90	81.27
23	1.00	23.00	3.40	125.30	83.53
24	1.00	24.00	3.30	128.60	85.73
25	1.00	25.00	3.10	131.70	87.80
	25.00		131.70		

Table A-8

Production Data for Simultaneous Water & Gas Drive At 1cc/min For Well # 6									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2.00	2.00	2.00	2.00	0.00	0.00	2.00	1.16	0.00
2	4.00	6.00	3.20	5.20	0.00	0.00	3.20	3.01	0.00
3	4.00	10.00	3.50	8.70	0.00	0.00	3.50	5.03	0.00
4	4.00	14.00	3.50	12.20	0.00	0.00	3.50	7.05	0.00
5	4.00	18.00	4.00	16.20	0.00	0.00	4.00	9.36	0.00
6	4.00	22.00	4.00	20.20	0.00	0.00	4.00	11.68	0.00
7	4.00	26.00	3.70	23.90	0.00	0.00	3.70	13.82	0.00
8	4.00	30.00	3.80	27.70	0.00	0.00	3.80	16.01	0.00
9	8.00	38.00	7.40	35.10	0.00	0.00	7.40	20.29	0.00
10	8.00	46.00	7.40	42.50	0.00	0.00	7.40	24.57	0.00
11	8.00	54.00	7.50	50.00	0.00	0.00	7.50	28.90	0.00
12	8.00	62.00	7.40	57.40	0.00	0.00	7.40	33.18	0.00
13	8.00	70.00	7.40	64.80	0.00	0.00	7.40	37.46	0.00
14	8.00	78.00	7.40	72.20	0.00	0.00	7.40	41.73	0.00
15	8.00	86.00	7.50	79.70	0.00	0.00	7.50	46.07	0.00
16	8.00	94.00	7.60	87.30	0.00	0.00	7.60	50.46	0.00
17	8.00	102.00	7.50	94.80	0.00	0.00	7.50	54.80	0.00
18	5.00	107.00	4.70	99.50	0.00	0.00	4.70	57.51	0.00
19	5.00	112.00	4.70	104.20	0.00	0.00	4.70	60.23	0.00
20	5.00	117.00	5.00	109.20	0.00	0.00	5.00	63.12	0.00
21	5.00	122.00	1.00	110.20	4.90	4.90	5.90	63.70	83.05
22	5.00	127.00	0.10	110.30	5.90	10.80	6.00	63.76	98.33
23	5.00	132.00	0.10	110.40	5.90	16.70	6.00	63.82	98.33
24	5.00	137.00	0.10	110.50	6.00	22.70	6.10	63.87	98.36
25	5.00	142.00	0.10	110.60	5.90	28.60	6.00	63.93	98.33
26	5.00	147.00	0.10	110.70	5.90	34.50	6.00	63.99	98.33
27	5.00	152.00	0.10	110.80	5.90	40.40	6.00	64.05	98.33
28	5.00	157.00	0.10	110.90	5.90	46.30	6.00	64.10	98.33
29	5.00	162.00	0.10	111.00	6.00	52.30	6.10	64.16	98.36
30	5.00	167.00	0.10	111.10	6.00	58.30	6.10	64.22	98.36
31	5.00	172.00	0.10	111.20	5.80	64.10	5.90	64.28	98.31
32	5.00	177.00	0.10	111.30	5.90	70.00	6.00	64.34	98.33
33	5.00	182.00	0.10	111.40	6.00	76.00	6.10	64.39	98.36
34	5.00	187.00	0.10	111.50	5.90	81.90	6.00	64.45	98.33
35	5.00	192.00	0.10	111.60	5.90	87.80	6.00	64.51	98.33
	192.00		111.60		87.80		199.40		

Table A-9

Production Data for Simultaneous Water & Gas Drive At 2cc/min For Well # 6

Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2.00	2.00	3.60	3.60	0.00	0.00	3.60	2.08	0.00
2	2.00	4.00	4.00	7.60	0.00	0.00	4.00	4.39	0.00
3	2.00	6.00	3.80	11.40	0.00	0.00	3.80	6.59	0.00
4	2.00	8.00	3.70	15.10	0.00	0.00	3.70	8.73	0.00
5	2.00	10.00	3.80	18.90	0.00	0.00	3.80	10.92	0.00
6	2.00	12.00	4.00	22.90	0.00	0.00	4.00	13.24	0.00
7	2.00	14.00	3.90	26.80	0.00	0.00	3.90	15.49	0.00
8	2.00	16.00	3.90	30.70	0.00	0.00	3.90	17.75	0.00
9	2.00	18.00	4.00	34.70	0.00	0.00	4.00	20.06	0.00
10	2.00	20.00	3.90	38.60	0.00	0.00	3.90	22.31	0.00
11	2.00	22.00	3.90	42.50	0.00	0.00	3.90	24.57	0.00
12	2.00	24.00	3.90	46.40	0.00	0.00	3.90	26.82	0.00
13	2.00	26.00	4.10	50.50	0.00	0.00	4.10	29.19	0.00
14	2.00	28.00	4.10	54.60	0.00	0.00	4.10	31.56	0.00
15	2.00	30.00	4.10	58.70	0.00	0.00	4.10	33.93	0.00
16	2.00	32.00	4.10	62.80	0.00	0.00	4.10	36.30	0.00
17	2.00	34.00	4.10	66.90	0.00	0.00	4.10	38.67	0.00
18	2.00	36.00	4.00	70.90	0.00	0.00	4.00	40.98	0.00
19	2.00	38.00	4.10	75.00	0.00	0.00	4.10	43.35	0.00
20	2.00	40.00	4.00	79.00	0.00	0.00	4.00	45.66	0.00
21	2.00	42.00	4.10	83.10	0.00	0.00	4.10	48.03	0.00
22	2.00	44.00	3.90	87.00	0.00	0.00	3.90	50.29	0.00
23	2.00	46.00	4.00	91.00	0.00	0.00	4.00	52.60	0.00
24	2.00	48.00	3.60	94.60	0.00	0.00	3.60	54.68	0.00
25	2.00	50.00	4.00	98.60	0.00	0.00	4.00	56.99	0.00
26	2.00	52.00	3.70	102.30	0.00	0.00	3.70	59.13	0.00
27	2.00	54.00	3.70	106.00	0.00	0.00	3.70	61.27	0.00
28	2.00	56.00	3.80	109.80	0.00	0.00	3.80	63.47	0.00
29	2.00	58.00	4.00	113.80	0.00	0.00	4.00	65.78	0.00
30	2.00	60.00	3.90	117.70	0.00	0.00	3.90	68.03	0.00
31	2.00	62.00	3.50	121.20	0.00	0.00	3.50	70.06	0.00
32	2.00	64.00	3.00	124.20	0.00	0.00	3.00	70.30	0.00
33	2.00	66.00	3.00	127.20	0.00	0.00	3.00	70.77	0.00
34	2.00	68.00	2.80	130.00	0.00	0.00	2.80	71.01	0.00
35	2.00	70.00	2.40	132.40	0.00	0.00	2.40	71.25	0.00

Table A-9

Production Data for Simultaneous Water & Gas Drive At 2cc/min For Well # 6

Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
36	2.00	72.00	1.00	133.40	0.00	0.00	1.00	71.47	0.00
37	2.00	74.00	0.50	133.90	0.00	0.00	0.50	71.60	0.00
38	2.00	76.00	0.30	134.20	1.30	1.30	1.60	71.79	81.25
39	2.00	78.00	0.30	134.50	2.90	4.20	3.20	74.50	90.63
40	2.00	80.00	0.20	134.70	4.00	8.20	4.20	77.86	95.24
41	2.00	82.00	0.10	134.80	4.50	12.70	4.60	77.92	97.83
42	2.00	84.00	0.10	134.90	4.50	17.20	4.60	77.98	97.83
43	2.00	86.00	0.10	135.00	4.90	22.10	5.00	78.03	98.00
44	2.00	88.00	0.10	135.10	4.90	27.00	5.00	78.09	98.00
45	2.00	90.00	0.10	135.20	5.00	32.00	5.10	78.15	98.04
46	2.00	92.00	0.10	135.30	5.00	37.00	5.10	78.21	98.04
47	2.00	94.00	0.10	135.40	5.00	42.00	5.10	78.27	98.04
48	2.00	96.00	0.10	135.50	5.20	47.20	5.30	78.32	98.11
49	2.00	98.00	0.10	135.60	5.20	52.40	5.30	78.38	98.11
50	2.00	100.00	0.10	135.70	5.40	57.80	5.50	78.44	98.18
51	2.00	102.00	0.10	135.80	5.50	63.30	5.60	78.50	98.21
52	2.00	104.00	0.10	135.90	5.70	69.00	5.80	78.55	98.28
53	2.00	106.00	0.10	136.00	5.70	74.70	5.80	78.61	98.28
	106.00		136.00		74.70		210.70		

Table A-10

Production Data for Simultaneous Water & Gas Drive At 4cc/min For Well # 6									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.00	1.00	3.80	3.80	0.00	0.00	3.80	2.20	0.00
2	1.00	2.00	3.50	7.30	0.00	0.00	3.50	4.22	0.00
3	1.00	3.00	3.60	10.90	0.00	0.00	3.60	6.30	0.00
4	1.00	4.00	3.50	14.40	0.00	0.00	3.50	8.32	0.00
5	1.00	5.00	3.50	17.90	0.00	0.00	3.50	10.35	0.00
6	1.00	6.00	3.50	21.40	0.00	0.00	3.50	12.37	0.00
7	1.00	7.00	3.60	25.00	0.00	0.00	3.60	14.45	0.00
8	1.00	8.00	4.30	29.30	0.00	0.00	4.30	16.94	0.00
9	1.00	9.00	4.20	33.50	0.00	0.00	4.20	19.36	0.00
10	1.00	10.00	4.20	37.70	0.00	0.00	4.20	21.79	0.00
11	1.00	11.00	4.10	41.80	0.00	0.00	4.10	24.16	0.00
12	1.00	12.00	3.80	45.60	0.00	0.00	3.80	26.36	0.00
13	1.00	13.00	3.60	49.20	0.00	0.00	3.60	28.44	0.00
14	1.00	14.00	3.60	52.80	0.00	0.00	3.60	30.52	0.00
15	1.00	15.00	3.50	56.30	0.00	0.00	3.50	32.54	0.00
16	1.00	16.00	3.40	59.70	0.00	0.00	3.40	34.51	0.00
17	1.00	17.00	3.50	63.20	0.00	0.00	3.50	36.53	0.00
18	1.00	18.00	3.60	66.80	0.00	0.00	3.60	38.61	0.00
19	1.00	19.00	3.60	70.40	0.00	0.00	3.60	40.69	0.00
20	1.00	20.00	3.70	74.10	0.00	0.00	3.70	42.83	0.00
21	1.00	21.00	3.70	77.80	0.00	0.00	3.70	44.97	0.00
22	1.00	22.00	3.70	81.50	0.00	0.00	3.70	47.11	0.00
23	1.00	23.00	3.70	85.20	0.00	0.00	3.70	49.25	0.00
24	1.00	24.00	3.60	88.80	0.00	0.00	3.60	51.33	0.00
25	1.00	25.00	3.70	92.50	0.00	0.00	3.70	53.47	0.00
26	1.00	26.00	3.80	96.30	0.00	0.00	3.80	55.66	0.00
27	1.00	27.00	3.80	100.10	0.00	0.00	3.80	57.86	0.00
28	1.00	28.00	3.60	103.70	0.00	0.00	3.60	59.94	0.00
29	1.00	29.00	3.70	107.40	0.00	0.00	3.70	62.08	0.00
30	1.00	30.00	3.80	111.20	0.00	0.00	3.80	64.28	0.00
31	1.00	31.00	3.70	114.90	0.00	0.00	3.70	66.42	0.00
32	1.00	32.00	3.80	118.70	0.00	0.00	3.80	68.61	0.00
33	1.00	33.00	3.80	122.50	0.00	0.00	3.80	70.81	0.00
34	1.00	34.00	3.80	126.30	0.00	0.00	3.80	73.01	0.00

Table A-10

Production Data for Simultaneous Water & Gas Drive At 4cc/min For Well # 6									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
35	1.00	35.00	3.70	130.00	0.10	0.10	3.80	75.14	2.63
36	1.00	36.00	3.50	133.50	0.30	0.40	3.80	77.17	7.89
37	1.00	37.00	3.60	137.10	0.50	0.90	4.10	79.25	12.20
38	1.00	38.00	2.50	139.60	0.60	1.50	3.10	80.69	19.35
39	1.00	39.00	1.00	140.60	2.20	3.70	3.20	81.27	68.75
40	1.00	40.00	0.80	141.40	2.40	6.10	3.20	81.73	75.00
41	1.00	41.00	0.30	141.70	4.30	10.40	4.60	81.91	93.48
42	1.00	42.00	0.20	141.90	4.30	14.70	4.50	82.02	95.56
43	1.00	43.00	0.20	142.10	4.10	18.80	4.30	82.14	95.35
44	1.00	44.00	0.20	142.30	4.20	23.00	4.40	82.25	95.45
45	1.00	45.00	0.20	142.50	4.20	27.20	4.40	82.37	95.45
46	1.00	46.00	0.20	142.70	4.20	31.40	4.40	82.49	95.45
47	1.00	47.00	0.20	142.90	4.50	35.90	4.70	82.60	95.74
48	1.00	48.00	0.20	143.10	4.30	40.20	4.50	82.72	95.56
49	1.00	49.00	0.20	143.30	4.50	44.70	4.70	82.83	95.74
50	1.00	50.00	0.20	143.50	4.50	49.20	4.70	82.95	95.74
51	1.00	51.00	0.20	143.70	4.50	53.70	4.70	83.06	95.74
52	1.00	52.00	0.20	143.90	4.40	58.10	4.60	83.18	95.65
53	1.00	53.00	0.20	144.10	4.30	62.40	4.50	83.29	95.56
54	1.00	54.00	0.20	144.30	4.30	66.70	4.50	83.41	95.56
55	1.00	55.00	0.20	144.50	4.30	71.00	4.50	83.53	95.56
56	1.00	56.00	0.10	144.60	4.30	75.30	4.40	83.58	97.73
57	1.00	57.00	0.10	144.70	4.40	79.70	4.50	83.64	97.78
58	1.00	58.00	0.10	144.80	4.60	84.30	4.70	83.70	97.87
59	1.00	59.00	0.10	144.90	4.70	89.00	4.80	83.76	97.92
60	1.00	60.00	0.10	145.00	4.50	93.50	4.60	83.82	97.83
61	1.00	61.00	0.10	145.10	4.60	98.10	4.70	83.87	97.87
62	1.00	62.00	0.10	145.20	4.50	102.60	4.60	83.93	97.83
63	1.00	63.00	0.10	145.30	4.60	107.20	4.70	83.99	97.87
64	1.00	64.00	0.10	145.40	4.80	112.00	4.90	84.05	97.96
65	1.00	65.00	0.10	145.50	4.90	116.90	5.00	84.10	98.00
66	1.00	66.00	0.10	145.60	4.90	121.80	5.00	84.16	98.00
67	1.00	67.00	0.10	145.70	4.90	126.70	5.00	84.22	98.00
68	1.00	68.00	0.10	145.80	4.90	131.60	5.00	84.28	98.00
69	1.00	69.00	0.10	145.90	4.80	136.40	4.90	84.34	97.96

Table A-10

Production Data for Simultaneous Water & Gas Drive At 4cc/min For Well # 6									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
70	1.00	70.00	0.10	146.00	4.20	140.60	4.30	84.39	97.67
71	1.00	71.00	0.10	146.10	4.10	144.70	4.20	84.45	97.62
72	1.00	72.00	0.10	146.20	3.90	148.60	4.00	84.51	97.50
73	1.00	73.00	0.10	146.30	4.00	152.60	4.10	84.57	97.56
74	1.00	74.00	0.10	146.40	4.10	156.70	4.20	84.62	97.62
75	1.00	75.00	0.10	146.50	4.00	160.70	4.10	84.68	97.56
76	1.00	76.00	0.10	146.60	4.10	164.80	4.20	84.74	97.62
77	1.00	77.00	0.10	146.70	4.60	169.40	4.70	84.80	97.87
78	1.00	78.00	0.10	146.80	4.50	173.90	4.60	84.86	97.83
79	1.00	79.00	0.10	146.90	4.60	178.50	4.70	84.91	97.87
80	1.00	80.00	0.10	147.00	4.40	182.90	4.50	84.97	97.78
81	1.00	81.00	0.10	147.10	4.30	187.20	4.40	85.03	97.73
82	1.00	82.00	0.10	147.20	4.30	191.50	4.40	85.09	97.73
83	1.00	83.00	0.10	147.30	4.20	195.70	4.30	85.14	97.67
84	1.00	84.00	0.10	147.40	4.30	200.00	4.40	85.20	97.73
85	1.00	85.00	0.10	147.50	4.30	204.30	4.40	85.26	97.73
86	1.00	86.00	0.10	147.60	4.30	208.60	4.40	85.32	97.73
87	1.00	87.00	0.10	147.70	4.40	213.00	4.50	85.38	97.78
88	1.00	88.00	0.10	147.80	4.30	217.30	4.40	85.43	97.73
89	1.00	89.00	0.10	147.90	4.20	221.50	4.30	85.49	97.67
90	1.00	90.00	0.10	148.00	4.30	225.80	4.40	85.55	97.73
91	1.00	91.00	0.10	148.10	4.20	230.00	4.30	85.61	97.67
	91.00		148.10		230.00		378.10		

Table A-11

Production Data for Simultaneous Water & Gas Drive At 7.6cc/min For Well # 6									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1-	1.00	1.00	7.90	7.90	0.00	0.00	7.90	4.57	0.00
2	1.00	2.00	8.00	15.90	0.00	0.00	8.00	9.19	0.00
3	1.00	3.00	7.80	23.70	0.00	0.00	7.80	13.70	0.00
4	1.00	4.00	8.00	31.70	0.00	0.00	8.00	18.32	0.00
5	1.00	5.00	8.10	39.80	0.00	0.00	8.10	23.01	0.00
6	1.00	6.00	8.00	47.80	0.00	0.00	8.00	27.63	0.00
7	1.00	7.00	8.00	55.80	0.00	0.00	8.00	32.25	0.00
8	1.00	8.00	7.80	63.60	0.00	0.00	7.80	36.76	0.00
9	1.00	9.00	7.90	71.50	0.00	0.00	7.90	41.33	0.00
10	1.00	10.00	8.10	79.60	0.00	0.00	8.10	46.01	0.00
11	1.00	11.00	7.70	87.30	0.00	0.00	7.70	50.46	0.00
12	1.00	12.00	8.00	95.30	0.00	0.00	8.00	55.09	0.00
13	1.00	13.00	7.80	103.10	0.00	0.00	7.80	59.60	0.00
14	1.00	14.00	7.10	110.20	0.00	0.00	7.10	63.70	0.00
15	1.00	15.00	7.70	117.90	0.00	0.00	7.70	68.15	0.00
16	1.00	16.00	7.80	125.70	0.00	0.00	7.80	72.66	0.00
17	1.00	17.00	7.70	133.40	0.00	0.00	7.70	77.11	0.00
18	1.00	18.00	8.00	141.40	0.10	0.10	8.10	81.73	1.23
19	1.00	19.00	7.40	148.80	0.50	0.60	7.90	86.01	6.33
20	1.00	20.00	4.10	152.90	1.60	2.20	5.70	88.38	28.07
21	1.00	21.00	3.20	156.10	2.10	4.30	5.30	90.23	39.62
22	1.00	22.00	2.40	158.50	2.30	6.60	4.70	91.62	48.94
23	1.00	23.00	1.70	160.20	3.10	9.70	4.80	92.60	64.58
24	1.00	24.00	1.40	161.60	5.30	15.00	6.70	93.41	79.10
25	1.00	25.00	1.00	162.60	6.00	21.00	7.00	93.99	85.71
26	1.00	26.00	1.00	163.60	6.50	27.50	7.50	94.57	86.67
27	1.00	27.00	0.80	164.40	6.20	33.70	7.00	95.03	88.57
28	1.00	28.00	0.50	164.90	7.00	40.70	7.50	95.32	93.33
29	1.00	29.00	0.40	165.30	6.90	47.60	7.30	95.55	94.52
30	1.00	30.00	0.40	165.70	7.00	54.60	7.40	95.78	94.59
31	1.00	31.00	0.40	166.10	7.10	61.70	7.50	96.01	94.67
32	1.00	32.00	0.30	166.40	7.00	68.70	7.30	96.18	95.89
33	1.00	33.00	0.30	166.70	7.50	76.20	7.80	96.36	96.15
34	1.00	34.00	0.20	166.90	7.60	83.80	7.80	96.47	97.44
35	1.00	35.00	0.20	167.10	7.70	91.50	7.90	96.59	97.47

Table A-11

Production Data for Simultaneous Water & Gas Drive At 7.6cc/min For Well # 6									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
36	1.00	36.00	0.20	167.30	7.50	99.00	7.70	96.71	97.40
37	1.00	37.00	0.20	167.50	7.50	106.50	7.70	96.82	97.40
38	1.00	38.00	0.20	167.70	7.30	113.80	7.50	96.94	97.33
39	1.00	39.00	0.20	167.90	7.50	121.30	7.70	97.05	97.40
40	1.00	40.00	0.10	168.00	7.40	128.70	7.50	97.11	98.67
41	1.00	41.00	0.10	168.10	7.10	135.80	7.20	97.17	98.61
42	1.00	42.00	0.10	168.20	7.80	143.60	7.90	97.23	98.73
43	1.00	43.00	0.10	168.30	7.80	151.40	7.90	97.28	98.73
44	1.00	44.00	0.10	168.40	8.00	159.40	8.10	97.34	98.77
45	1.00	45.00	0.10	168.50	7.90	167.30	8.00	97.40	98.75
46	1.00	46.00	0.10	168.60	7.90	175.20	8.00	97.46	98.75
47	1.00	47.00	0.10	168.70	7.70	182.90	7.80	97.51	98.72
48	1.00	48.00	0.10	168.80	7.80	190.70	7.90	97.57	98.73
49	1.00	49.00	0.10	168.90	7.60	198.30	7.70	97.63	98.70
50	1.00	50.00	0.10	169.00	7.80	206.10	7.90	97.69	98.73
51	1.00	51.00	0.10	169.10	7.50	213.60	7.60	97.75	98.68
52	1.00	52.00	0.10	169.20	7.80	221.40	7.90	97.80	98.73
53	1.00	53.00	0.10	169.30	7.30	228.70	7.40	97.86	98.65
54	1.00	54.00	0.10	169.40	7.50	236.20	7.60	97.92	98.68
55	1.00	55.00	0.10	169.50	7.70	243.90	7.80	97.98	98.72
56	1.00	56.00	0.10	169.60	8.00	251.90	8.10	98.03	98.77
57	1.00	57.00	0.10	169.70	7.80	259.70	7.90	98.09	98.73
58	1.00	58.00	0.10	169.80	7.70	267.40	7.80	98.15	98.72
59	1.00	59.00	0.10	169.90	7.80	275.20	7.90	98.21	98.73
60	1.00	60.00	0.10	170.00	8.00	283.20	8.10	98.27	98.77
61	1.00	61.00	0.10	170.10	7.80	291.00	7.90	98.32	98.73
	61.00		170.10		291.00		461.10		

Table A-12

Production Data for Simultaneous Water & Gas Drive At 1cc/min For Well # 7									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	4.00	4.00	3.80	3.80	0.00	0.00	3.80	2.20	0.00
2	4.00	8.00	4.00	7.80	0.00	0.00	4.00	4.51	0.00
3	4.00	12.00	3.90	11.70	0.00	0.00	3.90	6.76	0.00
4	4.00	16.00	3.90	15.60	0.00	0.00	3.90	9.02	0.00
5	4.00	20.00	4.00	19.60	0.00	0.00	4.00	11.33	0.00
6	4.00	24.00	4.00	23.60	0.00	0.00	4.00	13.64	0.00
7	4.00	28.00	3.80	27.40	0.00	0.00	3.80	15.84	0.00
8	4.00	32.00	3.90	31.30	0.00	0.00	3.90	18.09	0.00
9	4.00	36.00	3.80	35.10	0.00	0.00	3.80	20.29	0.00
10	4.00	40.00	4.00	39.10	0.00	0.00	4.00	22.60	0.00
11	4.00	44.00	4.00	43.10	0.00	0.00	4.00	24.91	0.00
12	4.00	48.00	3.80	46.90	0.00	0.00	3.80	27.11	0.00
13	4.00	52.00	3.90	50.80	0.00	0.00	3.90	29.36	0.00
14	4.00	56.00	4.00	54.80	0.00	0.00	4.00	31.68	0.00
15	4.00	60.00	3.90	58.70	0.00	0.00	3.90	33.93	0.00
16	4.00	64.00	3.90	62.60	0.00	0.00	3.90	36.18	0.00
17	4.00	68.00	3.70	66.30	0.00	0.00	3.70	38.32	0.00
18	4.00	72.00	3.70	70.00	0.00	0.00	3.70	40.46	0.00
19	4.00	76.00	3.80	73.80	0.00	0.00	3.80	42.66	0.00
20	4.00	80.00	3.80	77.60	0.00	0.00	3.80	44.86	0.00
21	4.00	84.00	3.70	81.30	0.00	0.00	3.70	46.99	0.00
22	4.00	88.00	3.80	85.10	0.00	0.00	3.80	49.19	0.00
23	4.00	92.00	3.70	88.80	0.00	0.00	3.70	51.33	0.00
24	4.00	96.00	3.80	92.60	0.00	0.00	3.80	53.53	0.00
25	4.00	100.00	3.80	96.40	0.00	0.00	3.80	55.72	0.00
26	4.00	104.00	3.80	100.20	0.00	0.00	3.80	57.92	0.00
27	4.00	108.00	3.70	103.90	0.00	0.00	3.70	60.06	0.00
28	4.00	112.00	3.80	107.70	0.00	0.00	3.80	62.25	0.00
29	4.00	116.00	3.80	111.50	0.00	0.00	3.80	64.45	0.00
30	4.00	120.00	3.80	115.30	0.00	0.00	3.80	66.65	0.00
31	4.00	124.00	3.70	119.00	0.00	0.00	3.70	68.79	0.00
32	4.00	128.00	3.70	122.70	0.00	0.00	3.70	70.92	0.00
33	4.00	132.00	0.20	122.90	4.70	4.70	4.90	71.04	95.92
34	4.00	136.00	0.10	123.00	4.80	9.50	4.90	71.10	97.96
35	4.00	140.00	0.10	123.10	4.80	14.30	4.90	71.16	97.96

Table A-12

Production Data for Simultaneous Water & Gas Drive At 1cc/min For Well # 7

Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
36	4.00	144.00	0.10	123.20	4.70	19.00	4.80	71.21	97.92
37	4.00	148.00	0.10	123.30	4.70	23.70	4.80	71.27	97.92
38	4.00	152.00	0.10	123.40	4.70	28.40	4.80	71.33	97.92
39	4.00	156.00	0.10	123.50	4.60	33.00	4.70	71.39	97.87
40	4.00	160.00	0.10	123.60	4.70	37.70	4.80	71.45	97.92
41	4.00	164.00	0.10	123.70	4.70	42.40	4.80	71.50	97.92
42	4.00	168.00	0.10	123.80	4.70	47.10	4.80	71.56	97.92
43	4.00	172.00	0.10	123.90	4.70	51.80	4.80	71.62	97.92
44	4.00	176.00	0.10	124.00	4.60	56.40	4.70	71.68	97.87
	176.00		124.00		56.40		180.40		

Table A-13

Production Data for Simultaneous Water & Gas Drive At 2cc/min For Well # 7

Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2.00	2.00	3.90	3.90	0.00	0.00	3.90	2.25	0.00
2	2.00	4.00	4.00	7.90	0.00	0.00	4.00	4.57	0.00
3	2.00	6.00	3.80	11.70	0.00	0.00	3.80	6.76	0.00
4	2.00	8.00	3.70	15.40	0.00	0.00	3.70	8.90	0.00
5	2.00	10.00	3.70	19.10	0.00	0.00	3.70	11.04	0.00
6	2.00	12.00	3.70	22.80	0.00	0.00	3.70	13.18	0.00
7	2.00	14.00	3.90	26.70	0.00	0.00	3.90	15.43	0.00
8	2.00	16.00	3.80	30.50	0.00	0.00	3.80	17.63	0.00
9	2.00	18.00	3.90	34.40	0.00	0.00	3.90	19.88	0.00
10	2.00	20.00	3.70	38.10	0.00	0.00	3.70	22.02	0.00
11	2.00	22.00	3.70	41.80	0.00	0.00	3.70	24.16	0.00
12	2.00	24.00	3.80	45.60	0.00	0.00	3.80	26.36	0.00
13	2.00	26.00	3.80	49.40	0.00	0.00	3.80	28.55	0.00
14	2.00	28.00	3.70	53.10	0.00	0.00	3.70	30.69	0.00
15	2.00	30.00	3.80	56.90	0.00	0.00	3.80	32.89	0.00
16	2.00	32.00	3.70	60.60	0.00	0.00	3.70	35.03	0.00
17	2.00	34.00	3.90	64.50	0.00	0.00	3.90	37.28	0.00
18	2.00	36.00	3.90	68.40	0.00	0.00	3.90	39.54	0.00
19	2.00	38.00	3.90	72.30	0.00	0.00	3.90	41.79	0.00
20	2.00	40.00	3.80	76.10	0.00	0.00	3.80	43.99	0.00
21	2.00	42.00	3.80	79.90	0.00	0.00	3.80	46.18	0.00
22	2.00	44.00	3.80	83.70	0.00	0.00	3.80	48.38	0.00
23	2.00	46.00	3.90	87.60	0.00	0.00	3.90	50.64	0.00
24	2.00	48.00	3.90	91.50	0.00	0.00	3.90	52.89	0.00
25	2.00	50.00	3.90	95.40	0.00	0.00	3.90	55.14	0.00
26	2.00	52.00	3.90	99.30	0.00	0.00	3.90	57.40	0.00
27	2.00	54.00	3.80	103.10	0.00	0.00	3.80	59.60	0.00
28	2.00	56.00	3.80	106.90	0.00	0.00	3.80	61.79	0.00
29	2.00	58.00	3.90	110.80	0.00	0.00	3.90	64.05	0.00
30	2.00	60.00	3.80	114.60	0.00	0.00	3.80	66.24	0.00
31	2.00	62.00	3.80	118.40	0.00	0.00	3.80	68.44	0.00
32	2.00	64.00	3.70	122.10	0.00	0.00	3.70	70.58	0.00
33	2.00	66.00	1.00	123.10	1.60	1.60	2.60	71.16	61.54
34	2.00	68.00	0.80	123.90	1.70	3.30	2.50	71.62	68.00
35	2.00	70.00	0.60	124.50	1.80	5.10	2.40	71.97	75.00
36	2.00	72.00	0.50	125.00	1.50	6.60	2.00	72.25	75.00

Table A-13

Production Data for Simultaneous Water & Gas Drive At 2cc/min For Well # 7									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
37	2.00	74.00	0.40	125.40	1.60	8.20	2.00	72.49	80.00
38	2.00	76.00	0.40	125.80	2.30	10.50	2.70	72.72	85.19
39	2.00	78.00	0.30	126.10	3.00	13.50	3.30	72.89	90.91
40	2.00	80.00	0.30	126.40	3.50	17.00	3.80	73.06	92.11
41	2.00	82.00	0.30	126.70	3.40	20.40	3.70	73.24	91.89
42	2.00	84.00	0.20	126.90	3.20	23.60	3.40	73.35	94.12
43	2.00	86.00	0.20	127.10	3.20	26.80	3.40	73.47	94.12
44	2.00	88.00	0.20	127.30	3.30	30.10	3.50	73.58	94.29
45	2.00	90.00	0.20	127.50	3.40	33.50	3.60	73.70	94.44
46	2.00	92.00	0.20	127.70	4.00	37.50	4.20	73.82	95.24
47	2.00	94.00	0.30	128.00	4.00	41.50	4.30	73.99	93.02
48	2.00	96.00	0.20	128.20	4.00	45.50	4.20	74.10	95.24
49	2.00	98.00	0.30	128.50	4.00	49.50	4.30	74.28	93.02
50	2.00	100.00	0.30	128.80	4.00	53.50	4.30	74.45	93.02
51	2.00	102.00	0.20	129.00	3.90	57.40	4.10	74.57	95.12
52	2.00	104.00	0.20	129.20	3.70	61.10	3.90	74.68	94.87
53	2.00	106.00	0.20	129.40	4.40	65.50	4.60	74.80	95.65
54	2.00	108.00	0.20	129.60	3.90	69.40	4.10	74.91	95.12
55	2.00	110.00	0.20	129.80	3.90	73.30	4.10	75.03	95.12
56	2.00	112.00	0.10	129.90	4.00	77.30	4.10	75.09	97.56
57	2.00	114.00	0.10	130.00	4.00	81.30	4.10	75.14	97.56
58	2.00	116.00	0.10	130.10	4.30	85.60	4.40	75.20	97.73
59	2.00	118.00	0.10	130.20	3.90	89.50	4.00	75.26	97.50
60	2.00	120.00	0.10	130.30	3.90	93.40	4.00	75.32	97.50
61	2.00	122.00	0.10	130.40	3.90	97.30	4.00	75.38	97.50
62	2.00	124.00	0.10	130.50	3.70	101.00	3.80	75.43	97.37
63	2.00	126.00	0.10	130.60	3.70	104.70	3.80	75.49	97.37
64	2.00	128.00	0.10	130.70	3.60	108.30	3.70	75.55	97.30
65	2.00	130.00	0.10	130.80	3.40	111.70	3.50	75.61	97.14
66	2.00	132.00	0.10	130.90	3.80	115.50	3.90	75.66	97.44
67	2.00	134.00	0.10	131.00	3.90	119.40	4.00	75.72	97.50
68	2.00	136.00	0.10	131.10	3.90	123.30	4.00	75.78	97.50
69	2.00	138.00	0.10	131.20	3.90	127.20	4.00	75.84	97.50
70	2.00	140.00	0.10	131.30	4.00	131.20	4.10	75.90	97.56
71	2.00	142.00	0.10	131.40	4.00	135.20	4.10	75.95	97.56
72	2.00	144.00	0.10	131.50	3.90	139.10	4.00	76.01	97.50
73	2.00	146.00	0.10	131.60	3.80	142.90	3.90	76.07	97.44

Table A-13

Production Data for Simultaneous Water & Gas Drive At 2cc/min For Well # 7									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
74	2.00	148.00	0.10	131.70	3.90	146.80	4.00	76.13	97.50
75	2.00	150.00	0.10	131.80	3.90	150.70	4.00	76.18	97.50
76	2.00	152.00	0.10	131.90	3.90	154.60	4.00	76.24	97.50
77	2.00	154.00	0.10	132.00	3.90	158.50	4.00	76.30	97.50
78	2.00	156.00	0.10	132.10	3.90	162.40	4.00	76.36	97.50
79	2.00	158.00	0.10	132.20	3.90	166.30	4.00	76.42	97.50
80	2.00	160.00	0.10	132.30	3.90	170.20	4.00	76.47	97.50
81	2.00	162.00	0.10	132.40	3.80	174.00	3.90	76.53	97.44
	162.00		132.40		174.00		306.40		

Table A-14

Production Data for Simultaneous Water & Gas Drive At 4cc/min For Well # 7									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2.00	2.00	7.70	7.70	0.00	0.00	7.70	4.45	0.00
2	2.00	4.00	7.80	15.50	0.00	0.00	7.80	8.96	0.00
3	2.00	6.00	7.80	23.30	0.00	0.00	7.80	13.47	0.00
4	2.00	8.00	7.70	31.00	0.00	0.00	7.70	17.92	0.00
5	2.00	10.00	7.70	38.70	0.00	0.00	7.70	22.37	0.00
6	2.00	12.00	7.70	46.40	0.00	0.00	7.70	26.82	0.00
7	2.00	14.00	7.60	54.00	0.00	0.00	7.60	31.21	0.00
8	2.00	16.00	8.00	62.00	0.00	0.00	8.00	35.84	0.00
9	2.00	18.00	8.00	70.00	0.00	0.00	8.00	40.46	0.00
10	2.00	20.00	7.70	77.70	0.00	0.00	7.70	44.91	0.00
11	2.00	22.00	7.80	85.50	0.00	0.00	7.80	49.42	0.00
12	2.00	24.00	7.80	93.30	0.00	0.00	7.80	53.93	0.00
13	2.00	26.00	7.80	101.10	0.00	0.00	7.80	58.44	0.00
14	1.00	27.00	4.00	105.10	0.00	0.00	4.00	60.75	0.00
15	1.00	28.00	4.10	109.20	0.00	0.00	4.10	63.12	0.00
16	1.00	29.00	4.00	113.20	0.00	0.00	4.00	68.60	0.00
17	1.00	30.00	3.80	117.00	0.10	0.10	3.90	73.10	2.56
18	1.00	31.00	3.60	120.60	0.30	0.40	3.90	73.35	7.69
19	1.00	32.00	3.80	124.40	0.40	0.80	4.20	73.62	9.52
20	1.00	33.00	3.40	127.80	0.50	1.30	3.90	73.87	12.82
21	1.00	34.00	2.20	130.00	0.50	1.80	2.70	75.14	18.52
22	1.00	35.00	1.10	131.10	1.70	3.50	2.80	75.78	60.71
23	1.00	36.00	0.60	131.70	2.60	6.10	3.20	76.13	81.25
24	1.00	37.00	0.40	132.10	3.60	9.70	4.00	76.36	90.00
25	1.00	38.00	0.30	132.40	3.60	13.30	3.90	76.53	92.31
26	1.00	39.00	0.30	132.70	3.50	16.80	3.80	76.71	92.11
27	1.00	40.00	0.20	132.90	3.50	20.30	3.70	76.82	94.59
28	1.00	41.00	0.20	133.10	3.40	23.70	3.60	76.94	94.44
29	1.00	42.00	0.20	133.30	3.40	27.10	3.60	77.05	94.44
30	1.00	43.00	0.20	133.50	3.70	30.80	3.90	77.17	94.87
31	1.00	44.00	0.20	133.70	3.40	34.20	3.60	77.28	94.44
32	1.00	45.00	0.20	133.90	3.70	37.90	3.90	77.40	94.87
33	1.00	46.00	0.20	134.10	3.50	41.40	3.70	77.51	94.59
34	1.00	47.00	0.20	134.30	3.70	45.10	3.90	77.63	94.87
35	1.00	48.00	0.20	134.50	3.60	48.70	3.80	77.75	94.74

Table A-14

Production Data for Simultaneous Water & Gas Drive At 4cc/min For Well # 7									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
36	1.00	49.00	0.20	134.70	3.90	52.60	4.10	77.86	95.12
37	1.00	50.00	0.20	134.90	3.80	56.40	4.00	77.98	95.00
38	1.00	51.00	0.20	135.10	3.80	60.20	4.00	78.09	95.00
39	1.00	52.00	0.10	135.20	3.50	63.70	3.60	78.15	97.22
40	1.00	53.00	0.10	135.30	3.10	66.80	3.20	78.21	96.88
41	1.00	54.00	0.10	135.40	3.80	70.60	3.90	78.27	97.44
42	1.00	55.00	0.10	135.50	3.90	74.50	4.00	78.32	97.50
43	1.00	56.00	0.10	135.60	3.80	78.30	3.90	78.38	97.44
44	1.00	57.00	0.10	135.70	3.80	82.10	3.90	78.44	97.44
45	1.00	58.00	0.10	135.80	3.70	85.80	3.80	78.50	97.37
46	1.00	59.00	0.10	135.90	3.60	89.40	3.70	78.55	97.30
47	1.00	60.00	0.10	136.00	3.80	93.20	3.90	78.61	97.44
48	1.00	61.00	0.10	136.10	3.90	97.10	4.00	78.67	97.50
49	1.00	62.00	0.10	136.20	3.90	101.00	4.00	78.73	97.50
50	1.00	63.00	0.10	136.30	3.80	104.80	3.90	78.79	97.44
51	1.00	64.00	0.10	136.40	3.70	108.50	3.80	78.84	97.37
52	1.00	65.00	0.10	136.50	3.70	112.20	3.80	78.90	97.37
53	1.00	66.00	0.10	136.60	3.90	116.10	4.00	78.96	97.50
54	1.00	67.00	0.10	136.70	3.80	119.90	3.90	79.02	97.44
55	1.00	68.00	0.10	136.80	3.90	123.80	4.00	79.08	97.50
56	1.00	69.00	0.10	136.90	3.90	127.70	4.00	79.13	97.50
57	1.00	70.00	0.10	137.00	3.80	131.50	3.90	79.19	97.44
58	1.00	71.00	0.10	137.10	3.60	135.10	3.70	79.25	97.30
59	1.00	72.00	0.10	137.20	4.00	139.10	4.10	79.31	97.56
60	1.00	73.00	0.10	137.30	4.00	143.10	4.10	79.36	97.56
61	1.00	74.00	0.10	137.40	3.60	146.70	3.70	79.42	97.30
62	1.00	75.00	0.10	137.50	3.50	150.20	3.60	79.48	97.22
63	1.00	76.00	0.10	137.60	3.70	153.90	3.80	79.54	97.37
64	1.00	77.00	0.10	137.70	4.00	157.90	4.10	79.60	97.56
65	1.00	78.00	0.10	137.80	4.10	162.00	4.20	79.65	97.62
66	1.00	79.00	0.10	137.90	4.00	166.00	4.10	79.71	97.56
67	1.00	80.00	0.10	138.00	3.80	169.80	3.90	79.77	97.44
68	1.00	81.00	0.10	138.10	3.60	173.40	3.70	79.83	97.30
69	1.00	82.00	0.10	138.20	3.70	177.10	3.80	79.88	97.37
70	1.00	83.00	0.10	138.30	3.70	180.80	3.80	79.94	97.37
71	1.00	84.00	0.10	138.40	3.70	184.50	3.80	80.00	97.37

Table A-14

Production Data for Simultaneous Water & Gas Drive At 4cc/min For Well # 7

Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
72	1.00	85.00	0.10	138.50	4.10	188.60	4.20	80.06	97.62
73	1.00	86.00	0.10	138.60	4.20	192.80	4.30	80.12	97.67
74	1.00	87.00	0.10	138.70	4.40	197.20	4.50	80.17	97.78
75	1.00	88.00	0.10	138.80	4.40	201.60	4.50	80.23	97.78
76	1.00	89.00	0.10	138.90	4.10	205.70	4.20	80.29	97.62
77	1.00	90.00	0.10	139.00	4.20	209.90	4.30	80.35	97.67
78	1.00	91.00	0.10	139.10	4.20	214.10	4.30	80.40	97.67
79	1.00	92.00	0.10	139.20	4.30	218.40	4.40	80.46	97.73
80	1.00	93.00	0.10	139.30	4.40	222.80	4.50	80.52	97.78
81	1.00	94.00	0.10	139.40	4.40	227.20	4.50	80.58	97.78
82	1.00	95.00	0.10	139.50	4.40	231.60	4.50	80.64	97.78
83	1.00	96.00	0.10	139.60	4.40	236.00	4.50	80.69	97.78
84	1.00	97.00	0.10	139.70	4.50	240.50	4.60	80.75	97.83
85	1.00	98.00	0.10	139.80	4.50	245.00	4.60	80.81	97.83
86	1.00	99.00	0.10	139.90	4.50	249.50	4.60	80.87	97.83
87	1.00	100.00	0.10	140.00	4.40	253.90	4.50	80.92	97.78
88	1.00	101.00	0.10	140.10	4.40	258.30	4.50	80.98	97.78
89	1.00	102.00	0.10	140.20	4.30	262.60	4.40	81.04	97.73
90	1.00	103.00	0.10	140.30	4.20	266.80	4.30	81.10	97.67
91	1.00	104.00	0.10	140.40	4.30	271.10	4.40	81.16	97.73
92	1.00	105.00	0.10	140.50	4.40	275.50	4.50	81.21	97.78
93	1.00	106.00	0.10	140.60	4.50	280.00	4.60	81.27	97.83
94	1.00	107.00	0.10	140.70	4.50	284.50	4.60	81.33	97.83
95	1.00	108.00	0.10	140.80	4.40	288.90	4.50	81.39	97.78
	108.00		140.80		288.90		429.70		

Table A-15

Production Data for Simultaneous Water & Gas Drive At 7.6cc/min For Well # 7

Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.00	1.00	7.80	7.80	0.00	0.00	7.80	4.51	0.00
2	1.00	2.00	7.50	15.30	0.00	0.00	7.50	8.84	0.00
3	1.00	3.00	7.70	23.00	0.00	0.00	7.70	13.29	0.00
4	1.00	4.00	7.80	30.80	0.00	0.00	7.80	17.80	0.00
5	1.00	5.00	7.90	38.70	0.00	0.00	7.90	22.37	0.00
6	1.00	6.00	8.00	46.70	0.00	0.00	8.00	26.99	0.00
7	1.00	7.00	8.20	54.90	0.00	0.00	8.20	31.73	0.00
8	1.00	8.00	8.10	63.00	0.00	0.00	8.10	36.42	0.00
9	1.00	9.00	7.90	70.90	0.00	0.00	7.90	40.98	0.00
10	1.00	10.00	7.90	78.80	0.00	0.00	7.90	45.55	0.00
11	1.00	11.00	8.30	87.10	0.00	0.00	8.30	50.35	0.00
12	1.00	12.00	7.90	95.00	0.00	0.00	7.90	54.91	0.00
13	1.00	13.00	8.20	103.20	0.00	0.00	8.20	59.65	0.00
14	1.00	14.00	8.10	111.30	0.00	0.00	8.10	64.34	0.00
15	1.00	15.00	8.00	119.30	0.00	0.00	8.00	68.96	0.00
16	1.00	16.00	8.00	127.30	0.00	0.00	8.00	73.58	0.00
17	1.00	17.00	4.90	132.20	0.50	0.50	5.40	76.42	9.26
18	1.00	18.00	3.30	135.50	1.70	2.20	5.00	78.32	34.00
19	1.00	19.00	2.10	137.60	2.40	4.60	4.50	79.54	53.33
20	1.00	20.00	1.00	138.60	5.60	10.20	6.60	80.12	84.85
21	1.00	21.00	0.90	139.50	6.00	16.20	6.90	80.64	86.96
22	1.00	22.00	0.80	140.30	5.00	21.20	5.80	81.10	86.21
23	1.00	23.00	0.80	141.10	5.30	26.50	6.10	81.56	86.89
24	1.00	24.00	0.70	141.80	5.70	32.20	6.40	81.97	89.06
25	1.00	25.00	0.60	142.40	5.70	37.90	6.30	82.31	90.48
26	1.00	26.00	0.60	143.00	5.00	42.90	5.60	82.66	89.29
27	1.00	27.00	0.60	143.60	5.50	48.40	6.10	83.01	90.16
28	1.00	28.00	0.60	144.20	5.60	54.00	6.20	83.35	90.32
29	1.00	29.00	0.50	144.70	5.40	59.40	5.90	83.64	91.53
30	1.00	30.00	0.60	145.30	5.80	65.20	6.40	83.99	90.63
31	1.00	31.00	0.50	145.80	6.10	71.30	6.60	84.28	92.42
32	1.00	32.00	0.50	146.30	6.30	77.60	6.80	84.57	92.65
33	1.00	33.00	0.50	146.80	6.50	84.10	7.00	84.86	92.86
34	1.00	34.00	0.50	147.30	6.30	90.40	6.80	85.14	92.65
35	1.00	35.00	0.50	147.80	6.30	96.70	6.80	85.43	92.65
36	1.00	36.00	0.50	148.30	6.80	103.50	7.30	85.72	93.15

Table A-15

Production Data for Simultaneous Water & Gas Drive At 7.6cc/min For Well # 7									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
37	1.00	37.00	0.50	148.80	6.50	110.00	7.00	86.01	92.86
38	1.00	38.00	0.40	149.20	6.60	116.60	7.00	86.24	94.29
39	1.00	39.00	0.40	149.60	6.50	123.10	6.90	86.47	94.20
40	1.00	40.00	0.40	150.00	6.90	130.00	7.30	86.71	94.52
41	1.00	41.00	0.40	150.40	6.40	136.40	6.80	86.94	94.12
42	1.00	42.00	0.40	150.80	6.90	143.30	7.30	87.17	94.52
43	1.00	43.00	0.40	151.20	7.00	150.30	7.40	87.40	94.59
44	1.00	44.00	0.40	151.60	6.90	157.20	7.30	87.63	94.52
45	1.00	45.00	0.40	152.00	6.60	163.80	7.00	87.86	94.29
46	1.00	46.00	0.40	152.40	7.00	170.80	7.40	88.09	94.59
47	1.00	47.00	0.40	152.80	7.40	178.20	7.80	88.32	94.87
48	1.00	48.00	0.30	153.10	7.20	185.40	7.50	88.50	96.00
49	1.00	49.00	0.30	153.40	7.10	192.50	7.40	88.67	95.95
50	1.00	50.00	0.40	153.80	7.40	199.90	7.80	88.90	94.87
51	1.00	51.00	0.30	154.10	7.10	207.00	7.40	89.08	95.95
52	1.00	52.00	0.30	154.40	7.10	214.10	7.40	89.25	95.95
53	1.00	53.00	0.30	154.70	7.50	221.60	7.80	89.42	96.15
54	1.00	54.00	0.30	155.00	7.40	229.00	7.70	89.60	96.10
55	1.00	55.00	0.30	155.30	7.50	236.50	7.80	89.77	96.15
56	1.00	56.00	0.30	155.60	7.20	243.70	7.50	89.94	96.00
57	1.00	57.00	0.30	155.90	7.70	251.40	8.00	90.12	96.25
58	1.00	58.00	0.30	156.20	8.20	259.60	8.50	90.29	96.47
59	1.00	59.00	0.20	156.40	8.00	267.60	8.20	90.40	97.56
60	1.00	60.00	0.20	156.60	8.10	275.70	8.30	90.52	97.59
61	1.00	61.00	0.20	156.80	8.10	283.80	8.30	90.64	97.59
62	1.00	62.00	0.20	157.00	8.10	291.90	8.30	90.75	97.59
63	1.00	63.00	0.20	157.20	8.00	299.90	8.20	90.87	97.56
64	1.00	64.00	0.20	157.40	8.30	308.20	8.50	90.98	97.65
65	1.00	65.00	0.20	157.60	8.40	316.60	8.60	91.10	97.67
66	1.00	66.00	0.20	157.80	8.40	325.00	8.60	91.21	97.67
67	1.00	67.00	0.20	158.00	8.30	333.30	8.50	91.33	97.65
68	1.00	68.00	0.20	158.20	7.90	341.20	8.10	91.45	97.53
69	1.00	69.00	0.20	158.40	8.00	349.20	8.20	91.56	97.56
70	1.00	70.00	0.20	158.60	7.80	357.00	8.00	91.68	97.50
71	1.00	71.00	0.10	158.70	8.10	365.10	8.20	91.73	98.78
72	1.00	72.00	0.10	158.80	8.20	373.30	8.30	91.79	98.80
73	1.00	73.00	0.10	158.90	8.20	381.50	8.30	91.85	98.80

Table A-15

Production Data for Simultaneous Water & Gas Drive At 7.6cc/min For Well # 7									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
74	1.00	74.00	0.10	159.00	8.10	389.60	8.20	91.91	98.78
75	1.00	75.00	0.20	159.20	8.00	397.60	8.20	92.02	97.56
76	1.00	76.00	0.20	159.40	8.00	405.60	8.20	92.14	97.56
77	1.00	77.00	0.10	159.50	8.40	414.00	8.50	92.20	98.82
78	1.00	78.00	0.10	159.60	8.00	422.00	8.10	92.25	98.77
79	1.00	79.00	0.10	159.70	8.00	430.00	8.10	92.31	98.77
80	1.00	80.00	0.10	159.80	8.00	438.00	8.10	92.37	98.77
81	1.00	81.00	0.10	159.90	8.00	446.00	8.10	92.43	98.77
82	1.00	82.00	0.10	160.00	8.00	454.00	8.10	92.49	98.77
83	1.00	83.00	0.10	160.10	8.20	462.20	8.30	92.54	98.80
84	1.00	84.00	0.10	160.20	8.00	470.20	8.10	92.60	98.77
85	1.00	85.00	0.10	160.30	8.20	478.40	8.30	92.66	98.80
86	1.00	86.00	0.10	160.40	8.00	486.40	8.10	92.72	98.77
87	1.00	87.00	0.10	160.50	8.20	494.60	8.30	92.77	98.80
88	1.00	88.00	0.10	160.60	8.10	502.70	8.20	92.83	98.78
89	1.00	89.00	0.10	160.70	7.90	510.60	8.00	92.89	98.75
90	1.00	90.00	0.10	160.80	8.20	518.80	8.30	92.95	98.80
91	1.00	91.00	0.10	160.90	8.00	526.80	8.10	93.01	98.77
92	1.00	92.00	0.10	161.00	8.40	535.20	8.50	93.06	98.82
93	1.00	93.00	0.10	161.10	8.10	543.30	8.20	93.12	98.78
94	1.00	94.00	0.10	161.20	8.20	551.50	8.30	93.18	98.80
95	1.00	95.00	0.10	161.30	8.20	559.70	8.30	93.24	98.80
96	1.00	96.00	0.10	161.40	8.20	567.90	8.30	93.29	98.80
97	1.00	97.00	0.10	161.50	8.40	576.30	8.50	93.35	98.82
98	1.00	98.00	0.10	161.60	8.30	584.60	8.40	93.41	98.81
99	1.00	99.00	0.10	161.70	8.30	592.90	8.40	93.47	98.81
100	1.00	100.00	0.10	161.80	8.10	601.00	8.20	93.53	98.78
101	1.00	101.00	0.10	161.90	8.00	609.00	8.10	93.58	98.77
102	1.00	102.00	0.10	162.00	8.00	617.00	8.10	93.64	98.77
103	1.00	103.00	0.10	162.10	8.00	625.00	8.10	93.70	98.77
	103.00		162.10		625.00		787.10		

Table A-16

Production Data for Simultaneous Water & Gas Drive At 1cc/min For Well # 8									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	3.00	3.00	3.10	3.10	0.00	0.00	3.10	1.79	0.00
2	8.00	11.00	7.60	10.70	0.00	0.00	7.60	6.18	0.00
3	8.00	19.00	8.00	18.70	0.00	0.00	8.00	10.81	0.00
4	8.00	27.00	7.90	26.60	0.00	0.00	7.90	15.38	0.00
5	8.00	35.00	8.10	34.70	0.00	0.00	8.10	20.06	0.00
6	8.00	43.00	8.10	42.80	0.00	0.00	8.10	24.74	0.00
7	4.00	47.00	3.90	46.70	0.00	0.00	3.90	26.99	0.00
8	4.00	51.00	4.00	50.70	0.00	0.00	4.00	29.31	0.00
9	4.00	55.00	4.20	54.90	0.00	0.00	4.20	31.73	0.00
10	4.00	59.00	4.10	59.00	0.00	0.00	4.10	34.10	0.00
11	4.00	63.00	3.90	62.90	0.00	0.00	3.90	36.36	0.00
12	4.00	67.00	1.50	64.40	3.00	3.00	4.50	37.23	66.67
13	4.00	71.00	0.30	64.70	4.70	7.70	5.00	37.40	94.00
14	4.00	75.00	0.30	65.00	4.60	12.30	4.90	37.57	93.88
15	4.00	79.00	0.30	65.30	4.50	16.80	4.80	37.75	93.75
16	4.00	83.00	0.30	65.60	4.60	21.40	4.90	37.92	93.88
17	4.00	87.00	0.20	65.80	4.60	26.00	4.80	38.03	95.83
18	4.00	91.00	0.20	66.00	4.60	30.60	4.80	38.15	95.83
19	4.00	95.00	0.20	66.20	4.70	35.30	4.90	38.27	95.92
20	4.00	99.00	0.20	66.40	4.80	40.10	5.00	38.38	96.00
21	4.00	103.00	0.20	66.60	4.80	44.90	5.00	38.50	96.00
22	4.00	107.00	0.10	66.70	4.70	49.60	4.80	38.55	97.92
23	4.00	111.00	0.10	66.80	4.70	54.30	4.80	38.61	97.92
24	4.00	115.00	0.10	66.90	4.70	59.00	4.80	38.67	97.92
25	4.00	119.00	0.10	67.00	4.70	63.70	4.80	38.73	97.92
	119.00		67.00		63.70		130.70		

Table A-17

Production Data for Simultaneous Water & Gas Drive At 2cc/min For Well # 8

Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2.00	2.00	3.80	3.80	0.00	0.00	3.80	2.20	0.00
2	2.00	4.00	3.70	7.50	0.00	0.00	3.70	4.34	0.00
3	2.00	6.00	3.60	11.10	0.00	0.00	3.60	6.42	0.00
4	2.00	8.00	3.90	15.00	0.00	0.00	3.90	8.67	0.00
5	2.00	10.00	4.00	19.00	0.00	0.00	4.00	10.98	0.00
6	2.00	12.00	4.00	23.00	0.00	0.00	4.00	13.29	0.00
7	4.00	16.00	8.00	31.00	0.00	0.00	8.00	17.92	0.00
8	4.00	20.00	7.80	38.80	0.00	0.00	7.80	22.43	0.00
9	4.00	24.00	7.80	46.60	0.00	0.00	7.80	26.94	0.00
10	4.00	28.00	7.70	54.30	0.00	0.00	7.70	31.39	0.00
11	2.00	30.00	4.00	58.30	0.00	0.00	4.00	33.70	0.00
12	2.00	32.00	3.90	62.20	0.00	0.00	3.90	35.95	0.00
13	2.00	34.00	3.90	66.10	0.00	0.00	3.90	38.21	0.00
14	2.00	36.00	4.00	70.10	0.00	0.00	4.00	40.52	0.00
15	2.00	38.00	4.00	74.10	0.00	0.00	4.00	42.83	0.00
16	2.00	40.00	2.80	76.90	1.70	1.70	4.50	44.45	37.78
17	2.00	42.00	0.20	77.10	4.30	6.00	4.50	44.57	95.56
18	2.00	44.00	0.10	77.20	4.50	10.50	4.60	44.62	97.83
19	2.00	46.00	0.10	77.30	4.40	14.90	4.50	44.68	97.78
20	2.00	48.00	0.10	77.40	4.40	19.30	4.50	44.74	97.78
21	2.00	50.00	0.10	77.50	4.40	23.70	4.50	44.80	97.78
22	2.00	52.00	0.10	77.60	4.50	28.20	4.60	44.86	97.83
23	2.00	54.00	0.10	77.70	4.40	32.60	4.50	44.91	97.78
24	2.00	56.00	0.10	77.80	4.40	37.00	4.50	44.97	97.78
25	2.00	58.00	0.10	77.90	4.30	41.30	4.40	45.03	97.73
26	2.00	60.00	0.10	78.00	4.40	45.70	4.50	45.09	97.78
27	2.00	62.00	0.10	78.10	4.30	50.00	4.40	45.14	97.73
28	4.00	66.00	0.10	78.20	9.00	59.00	9.10	45.20	98.90
29	4.00	70.00	0.10	78.30	9.00	68.00	9.10	45.26	98.90
30	4.00	74.00	0.10	78.40	9.00	77.00	9.10	45.32	98.90
31	4.00	78.00	0.10	78.50	9.00	86.00	9.10	45.38	98.90
32	4.00	82.00	0.10	78.60	9.10	95.10	9.20	45.43	98.91
33	4.00	86.00	0.10	78.70	9.20	104.30	9.30	45.49	98.92
34	4.00	90.00	0.10	78.80	9.10	113.40	9.20	45.55	98.91
35	4.00	94.00	0.10	78.90	9.10	122.50	9.20	45.61	98.91

Table A-17

Production Data for Simultaneous Water & Gas Drive At 2cc/min For Well # 8									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
36	4.00	98.00	0.10	79.00	9.10	131.60	9.20	45.66	98.91
37	4.00	102.00	0.10	79.10	9.10	140.70	9.20	45.72	98.91
38	4.00	106.00	0.10	79.20	9.10	149.80	9.20	45.78	98.91
39	4.00	110.00	0.10	79.30	9.10	158.90	9.20	45.84	98.91
40	2.00	112.00	0.10	79.40	4.20	163.10	4.30	45.90	97.67
	112.00		79.40		163.10		242.50		

Table A-18

Production Data for Simultaneous Water & Gas Drive At 4cc/min for Well # 8									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2.00	2.00	7.70	7.70	0.00	0.00	7.70	4.45	0.00
2	2.00	4.00	7.50	15.20	0.00	0.00	7.50	8.79	0.00
3	2.00	6.00	7.60	22.80	0.00	0.00	7.60	13.18	0.00
4	2.00	8.00	7.50	30.30	0.00	0.00	7.50	17.51	0.00
5	2.00	10.00	7.40	37.70	0.00	0.00	7.40	21.79	0.00
6	2.00	12.00	7.50	45.20	0.00	0.00	7.50	26.13	0.00
7	2.00	14.00	7.30	52.50	0.00	0.00	7.30	30.35	0.00
8	2.00	16.00	7.30	59.80	0.00	0.00	7.30	34.57	0.00
9	2.00	18.00	7.60	67.40	0.00	0.00	7.60	38.96	0.00
10	2.00	20.00	7.50	74.90	0.00	0.00	7.50	43.29	0.00
11	2.00	22.00	7.50	82.40	0.00	0.00	7.50	47.63	0.00
12	2.00	24.00	7.20	89.60	0.00	0.00	7.20	51.79	0.00
13	1.00	25.00	3.80	93.40	0.00	0.00	3.80	53.99	0.00
14	1.00	26.00	3.50	96.90	0.00	0.00	3.50	56.01	0.00
15	1.00	27.00	3.50	100.40	0.00	0.00	3.50	58.03	0.00
16	1.00	28.00	2.10	102.50	0.60	0.60	2.70	59.25	22.22
17	1.00	29.00	0.80	103.30	1.40	2.00	2.20	59.71	63.64
18	1.00	30.00	0.30	103.60	3.20	5.20	3.50	59.88	91.43
19	1.00	31.00	0.20	103.80	3.50	8.70	3.70	60.00	94.59
20	1.00	32.00	0.20	104.00	3.40	12.10	3.60	60.12	94.44
21	1.00	33.00	0.20	104.20	3.40	15.50	3.60	60.23	94.44
22	1.00	34.00	0.20	104.40	4.00	19.50	4.20	60.35	95.24
23	1.00	35.00	0.10	104.50	4.00	23.50	4.10	60.40	97.56
24	1.00	36.00	0.10	104.60	4.30	27.80	4.40	60.46	97.73
25	1.00	37.00	0.10	104.70	4.10	31.90	4.20	60.52	97.62
26	1.00	38.00	0.10	104.80	4.00	35.90	4.10	60.58	97.56
27	1.00	39.00	0.10	104.90	4.00	39.90	4.10	60.64	97.56
28	1.00	40.00	0.10	105.00	4.00	43.90	4.10	60.69	97.56
29	1.00	41.00	0.10	105.10	4.20	48.10	4.30	60.75	97.67
30	1.00	42.00	0.10	105.20	4.30	52.40	4.40	60.81	97.73
31	1.00	43.00	0.10	105.30	4.20	56.60	4.30	60.87	97.67
32	1.00	44.00	0.10	105.40	4.20	60.80	4.30	60.92	97.67
33	1.00	45.00	0.10	105.50	4.20	65.00	4.30	60.98	97.67
34	1.00	46.00	0.10	105.60	4.30	69.30	4.40	61.04	97.73
35	1.00	47.00	0.10	105.70	4.40	73.70	4.50	61.10	97.78
36	1.00	48.00	0.10	105.80	4.30	78.00	4.40	61.16	97.73
37	1.00	49.00	0.10	105.90	4.40	82.40	4.50	61.21	97.78
38	1.00	50.00	0.10	106.00	4.30	86.70	4.40	61.27	97.73

Table A-18

Production Data for Simultaneous Water & Gas Drive At 4cc/min for Well # 8									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
39	1.00	51.00	0.10	106.10	4.30	91.00	4.40	61.33	97.73
40	1.00	52.00	0.10	106.20	4.20	95.20	4.30	61.39	97.67
41	1.00	53.00	0.10	106.30	4.30	99.50	4.40	61.45	97.73
42	1.00	54.00	0.10	106.40	4.20	103.70	4.30	61.50	97.67
43	1.00	55.00	0.10	106.50	4.10	107.80	4.20	61.56	97.62
44	1.00	56.00	0.10	106.60	4.20	112.00	4.30	61.62	97.67
45	1.00	57.00	0.10	106.70	4.20	116.20	4.30	61.68	97.67
46	1.00	58.00	0.10	106.80	4.20	120.40	4.30	61.73	97.67
47	1.00	59.00	0.10	106.90	4.20	124.60	4.30	61.79	97.67
48	1.00	60.00	0.10	107.00	4.40	129.00	4.50	61.85	97.78
49	1.00	61.00	0.10	107.10	4.40	133.40	4.50	61.91	97.78
50	1.00	62.00	0.10	107.20	4.40	137.80	4.50	61.97	97.78
51	1.00	63.00	0.10	107.30	4.40	142.20	4.50	62.02	97.78
52	1.00	64.00	0.10	107.40	4.40	146.60	4.50	62.08	97.78
53	1.00	65.00	0.10	107.50	4.40	151.00	4.50	62.14	97.78
54	1.00	66.00	0.10	107.60	4.30	155.30	4.40	62.20	97.73
55	1.00	67.00	0.10	107.70	4.20	159.50	4.30	62.25	97.67
56	1.00	68.00	0.10	107.80	4.40	163.90	4.50	62.31	97.78
57	1.00	69.00	0.10	107.90	4.40	168.30	4.50	62.37	97.78
58	1.00	70.00	0.10	108.00	4.40	172.70	4.50	62.43	97.78
59	1.00	71.00	0.10	108.10	3.40	176.10	3.50	62.49	97.14
60	1.00	72.00	0.10	108.20	4.30	180.40	4.40	62.54	97.73
61	1.00	73.00	0.10	108.30	4.40	184.80	4.50	62.60	97.78
62	1.00	74.00	0.10	108.40	4.10	188.90	4.20	62.66	97.62
63	1.00	75.00	0.10	108.50	4.10	193.00	4.20	62.72	97.62
64	1.00	76.00	0.10	108.60	4.30	197.30	4.40	62.77	97.73
65	1.00	77.00	0.10	108.70	4.40	201.70	4.50	62.83	97.78
66	1.00	78.00	0.10	108.80	4.40	206.10	4.50	62.89	97.78
67	1.00	79.00	0.10	108.90	4.40	210.50	4.50	62.95	97.78
68	1.00	80.00	0.10	109.00	4.40	214.90	4.50	63.01	97.78
69	1.00	81.00	0.10	109.10	4.40	219.30	4.50	63.06	97.78
70	1.00	82.00	0.10	109.20	4.40	223.70	4.50	63.12	97.78
71	1.00	83.00	0.10	109.30	4.40	228.10	4.50	63.18	97.78
72	1.00	84.00	0.10	109.40	4.40	232.50	4.50	63.24	97.78
73	1.00	85.00	0.10	109.50	4.40	236.90	4.50	63.29	97.78
74	1.00	86.00	0.10	109.60	4.30	241.20	4.40	63.35	97.73
75	1.00	87.00	0.10	109.70	4.40	245.60	4.50	63.41	97.78
76	1.00	88.00	0.10	109.80	4.20	249.80	4.30	63.47	97.67
77	1.00	89.00	0.10	109.90	4.20	254.00	4.30	63.53	97.67

Table A-18

Production Data for Simultaneous Water & Gas Drive At 4cc/min for Well # 8									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
78	1.00	90.00	0.10	110.00	4.30	258.30	4.40	63.58	97.73
79	1.00	91.00	0.10	110.10	4.20	262.50	4.30	63.64	97.67
80	1.00	92.00	0.10	110.20	4.30	266.80	4.40	63.70	97.73
81	1.00	93.00	0.10	110.30	4.40	271.20	4.50	63.76	97.78
82	1.00	94.00	0.10	110.40	4.40	275.60	4.50	63.82	97.78
83	1.00	95.00	0.10	110.50	4.40	280.00	4.50	63.87	97.78
84	1.00	96.00	0.10	110.60	4.40	284.40	4.50	63.93	97.78
85	1.00	97.00	0.10	110.70	4.30	288.70	4.40	63.99	97.73
86	1.00	98.00	0.10	110.80	4.40	293.10	4.50	64.05	97.78
87	1.00	99.00	0.10	110.90	4.30	297.40	4.40	64.10	97.73
88	1.00	100.00	0.10	111.00	4.40	301.80	4.50	64.16	97.78
89	1.00	101.00	0.10	111.10	4.30	306.10	4.40	64.22	97.73
90	1.00	102.00	0.10	111.20	4.40	310.50	4.50	64.28	97.78
91	1.00	103.00	0.10	111.30	4.40	314.90	4.50	64.34	97.78
92	1.00	104.00	0.10	111.40	4.40	319.30	4.50	64.39	97.78
93	1.00	105.00	0.10	111.50	4.40	323.70	4.50	64.45	97.78
94	1.00	106.00	0.10	111.60	4.30	328.00	4.40	64.51	97.73
95	1.00	107.00	0.10	111.70	4.40	332.40	4.50	64.57	97.78
96	1.00	108.00	0.10	111.80	4.40	336.80	4.50	64.62	97.78
97	1.00	109.00	0.10	111.90	4.40	341.20	4.50	64.68	97.78
98	1.00	110.00	0.10	112.00	4.20	345.40	4.30	64.74	97.67
99	1.00	111.00	0.10	112.10	4.20	349.60	4.30	64.80	97.67
100	1.00	112.00	0.10	112.20	4.40	354.00	4.50	64.86	97.78
101	1.00	113.00	0.10	112.30	4.30	358.30	4.40	64.91	97.73
102	1.00	114.00	0.10	112.40	4.40	362.70	4.50	64.97	97.78
103	1.00	115.00	0.10	112.50	4.40	367.10	4.50	65.03	97.78
104	1.00	116.00	0.10	112.60	4.40	371.50	4.50	65.09	97.78
105	1.00	117.00	0.10	112.70	4.30	375.80	4.40	65.14	97.73
106	1.00	118.00	0.10	112.80	3.50	379.30	3.60	65.20	97.22
	118.00		112.80		379.30		492.10		

Table A-19

Production Data for Simultaneous Water & Gas Drive At 7.6cc/min for Well # 8									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.50	0.50	4.10	4.10	0.00	0.00	4.10	2.37	0.00
2	1.00	1.50	7.30	11.40	0.00	0.00	7.30	6.59	0.00
3	1.00	2.50	7.30	18.70	0.00	0.00	7.30	10.81	0.00
4	1.00	3.50	7.50	26.20	0.00	0.00	7.50	15.14	0.00
5	1.00	4.50	7.50	33.70	0.00	0.00	7.50	19.48	0.00
6	1.00	5.50	7.70	41.40	0.00	0.00	7.70	23.93	0.00
7	1.00	6.50	7.80	49.20	0.00	0.00	7.80	28.44	0.00
8	1.00	7.50	7.60	56.80	0.00	0.00	7.60	32.83	0.00
9	1.00	8.50	7.70	64.50	0.00	0.00	7.70	37.28	0.00
10	1.00	9.50	7.50	72.00	0.00	0.00	7.50	41.62	0.00
11	1.00	10.50	7.50	79.50	0.00	0.00	7.50	45.95	0.00
12	1.00	11.50	7.30	86.80	0.00	0.00	7.30	50.17	0.00
13	0.50	12.00	3.70	90.50	0.00	0.00	3.70	52.31	0.00
14	0.50	12.50	3.80	94.30	0.00	0.00	3.80	54.51	0.00
15	0.50	13.00	3.60	97.90	0.00	0.00	3.60	56.59	0.00
16	0.50	13.50	3.50	101.40	0.00	0.00	3.50	58.61	0.00
17	0.50	14.00	3.40	104.80	0.00	0.00	3.40	60.58	0.00
18	0.50	14.50	3.20	108.00	0.00	0.00	3.20	62.43	0.00
19	0.50	15.00	3.00	111.00	0.00	0.00	3.00	64.16	0.00
20	0.50	15.50	2.70	113.70	0.00	0.00	2.70	65.72	0.00
21	0.50	16.00	2.00	115.70	0.50	0.50	2.50	66.88	20.00
22	0.50	16.50	1.60	117.30	0.80	1.30	2.40	67.80	33.33
23	0.50	17.00	1.30	118.60	1.10	2.40	2.40	68.55	45.83
24	0.50	17.50	0.80	119.40	1.30	3.70	2.10	69.02	61.90
25	0.50	18.00	0.60	120.00	1.60	5.30	2.20	69.36	72.73
26	0.50	18.50	0.30	120.30	3.10	8.40	3.40	69.54	91.18
27	0.50	19.00	0.20	120.50	3.30	11.70	3.50	69.65	94.29
28	0.50	19.50	0.20	120.70	3.50	15.20	3.70	69.77	94.59
29	0.50	20.00	0.20	120.90	3.60	18.80	3.80	69.88	94.74
30	0.50	20.50	0.20	121.10	3.40	22.20	3.60	70.00	94.44
31	0.50	21.00	0.20	121.30	3.90	26.10	4.10	70.12	95.12
32	0.50	21.50	0.20	121.50	4.00	30.10	4.20	70.23	95.24
33	1.00	22.50	0.20	121.70	7.20	37.30	7.40	70.35	97.30
34	1.00	23.50	0.20	121.90	7.50	44.80	7.70	70.46	97.40
35	1.00	24.50	0.20	122.10	7.60	52.40	7.80	70.58	97.44
36	1.00	25.50	0.20	122.30	7.80	60.20	8.00	70.69	97.50

Table A-19

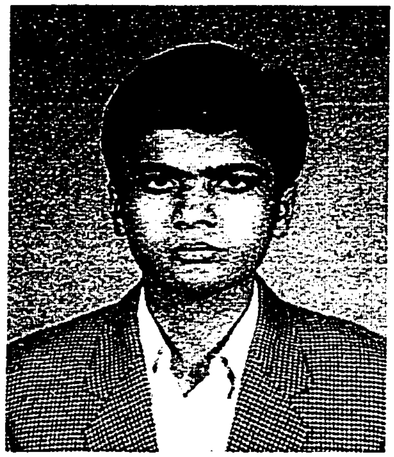
Production Data for Simultaneous Water & Gas Drive At 7.6cc/min for Well # 8									
Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
37	1.00	26.50	0.20	122.50	5.40	65.60	5.60	70.81	96.43
38	1.00	27.50	0.20	122.70	5.40	71.00	5.60	70.92	96.43
39	1.00	28.50	0.20	122.90	7.00	78.00	7.20	71.04	97.22
40	1.00	29.50	0.20	123.10	7.10	85.10	7.30	71.16	97.26
41	1.00	30.50	0.20	123.30	7.90	93.00	8.10	71.27	97.53
42	1.00	31.50	0.20	123.50	7.90	100.90	8.10	71.39	97.53
43	1.00	32.50	0.20	123.70	8.00	108.90	8.20	71.50	97.56
44	1.00	33.50	0.20	123.90	8.10	117.00	8.30	71.62	97.59
45	1.00	34.50	0.20	124.10	8.00	125.00	8.20	71.73	97.56
46	1.00	35.50	0.20	124.30	7.90	132.90	8.10	71.85	97.53
47	1.00	36.50	0.20	124.50	6.90	139.80	7.10	71.97	97.18
48	1.00	37.50	0.10	124.60	7.00	146.80	7.10	72.02	98.59
49	1.00	38.50	0.10	124.70	6.80	153.60	6.90	72.08	98.55
50	1.00	39.50	0.10	124.80	8.00	161.60	8.10	72.14	98.77
51	1.00	40.50	0.10	124.90	8.20	169.80	8.30	72.20	98.80
52	1.00	41.50	0.10	125.00	8.40	178.20	8.50	72.25	98.82
53	1.00	42.50	0.10	125.10	8.50	186.70	8.60	72.31	98.84
54	1.00	43.50	0.10	125.20	8.50	195.20	8.60	72.37	98.84
55	1.00	44.50	0.10	125.30	8.50	203.70	8.60	72.43	98.84
56	1.00	45.50	0.10	125.40	8.30	212.00	8.40	72.49	98.81
57	1.00	46.50	0.10	125.50	8.60	220.60	8.70	72.54	98.85
58	1.00	47.50	0.10	125.60	8.60	229.20	8.70	72.60	98.85
59	1.00	48.50	0.10	125.70	8.50	237.70	8.60	72.66	98.84
60	1.00	49.50	0.10	125.80	8.30	246.00	8.40	72.72	98.81
61	1.00	50.50	0.10	125.90	8.50	254.50	8.60	72.77	98.84
62	1.00	51.50	0.10	126.00	8.50	263.00	8.60	72.83	98.84
63	1.00	52.50	0.10	126.10	8.40	271.40	8.50	72.89	98.82
64	1.00	53.50	0.10	126.20	8.30	279.70	8.40	72.95	98.81
65	1.00	54.50	0.10	126.30	8.40	288.10	8.50	73.01	98.82
66	1.00	55.50	0.10	126.40	8.40	296.50	8.50	73.06	98.82
67	1.00	56.50	0.10	126.50	8.50	305.00	8.60	73.12	98.84
68	1.00	57.50	0.10	126.60	8.50	313.50	8.60	73.18	98.84
69	1.00	58.50	0.10	126.70	8.30	321.80	8.40	73.24	98.81
70	1.00	59.50	0.10	126.80	8.40	330.20	8.50	73.29	98.82
71	1.00	60.50	0.10	126.90	8.20	338.40	8.30	73.35	98.80
72	1.00	61.50	0.10	127.00	8.20	346.60	8.30	73.41	98.80
73	1.00	62.50	0.10	127.10	8.20	354.80	8.30	73.47	98.80

Table A-19

Production Data for Simultaneous Water & Gas Drive At 7.6cc/min for Well # 8

Tube No.	Time/tube (min)	Cum Time(min)	Oil/tube (cc)	Cum Oil (cc)	Wat/tube (cc)	Cum Water(cc)	Tot Vol/tube (cc)	Rec (% OOIP)	Water Cut (%)
74	1.00	63.50	0.10	127.20	8.20	363.00	8.30	73.53	98.80
75	1.00	64.50	0.10	127.30	8.10	371.10	8.20	73.58	98.78
76	1.00	65.50	0.10	127.40	8.20	379.30	8.30	73.64	98.80
77	1.00	66.50	0.10	127.50	8.20	387.50	8.30	73.70	98.80
78	1.00	67.50	0.10	127.60	8.10	395.60	8.20	73.76	98.78
79	1.00	68.50	0.10	127.70	8.00	403.60	8.10	73.82	98.77
80	1.00	69.50	0.10	127.80	8.10	411.70	8.20	73.87	98.78
81	1.00	70.50	0.10	127.90	8.00	419.70	8.10	73.93	98.77
82	1.00	71.50	0.10	128.00	8.00	427.70	8.10	73.99	98.77
83	1.00	72.50	0.10	128.10	8.00	435.70	8.10	74.05	98.77
84	1.00	73.50	0.10	128.20	8.00	443.70	8.10	74.10	98.77
85	1.00	74.50	0.10	128.30	7.90	451.60	8.00	74.16	98.75
86	1.00	75.50	0.10	128.40	7.80	459.40	7.90	74.22	98.73
87	1.00	76.50	0.10	128.50	7.60	467.00	7.70	74.28	98.70
88	1.00	77.50	0.10	128.60	7.70	474.70	7.80	74.34	98.72
89	1.00	78.50	0.10	128.70	7.70	482.40	7.80	74.39	98.72
90	1.00	79.50	0.10	128.80	7.60	490.00	7.70	74.45	98.70
91	1.00	80.50	0.10	128.90	7.60	497.60	7.70	74.51	98.70
92	1.00	81.50	0.10	129.00	7.60	505.20	7.70	74.57	98.70
93	1.00	82.50	0.10	129.10	7.60	512.80	7.70	74.62	98.70
94	1.00	83.50	0.10	129.20	7.50	520.30	7.60	74.68	98.68
95	1.00	84.50	0.10	129.30	7.50	527.80	7.60	74.74	98.68
96	1.00	85.50	0.10	129.40	7.40	535.20	7.50	74.80	98.67
97	1.00	86.50	0.10	129.50	7.40	542.60	7.50	74.86	98.67
98	1.00	87.50	0.10	129.60	7.40	550.00	7.50	74.91	98.67
99	1.00	88.50	0.10	129.70	7.50	557.50	7.60	74.97	98.68
100	0.50	89.00	0.10	129.80	3.80	561.30	3.90	75.03	97.44
	89.00		129.80		561.30		691.10		

Vita



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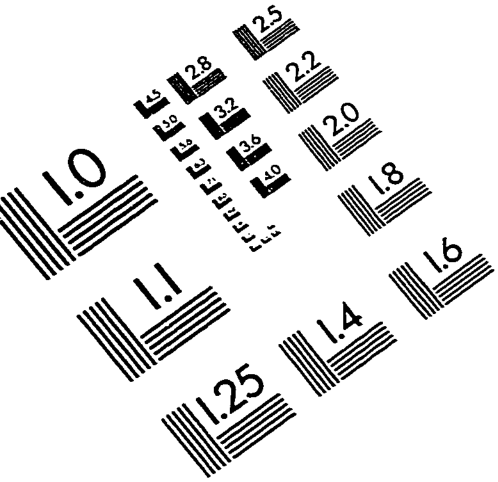
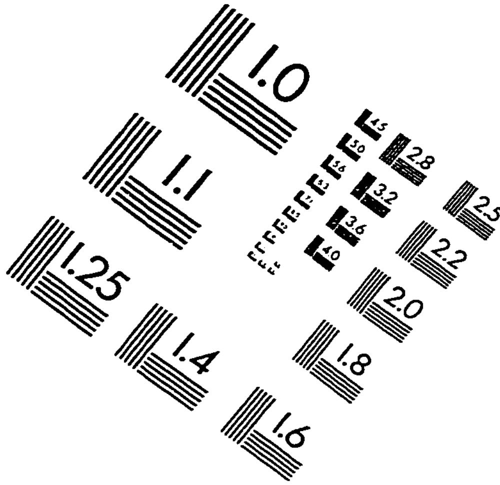
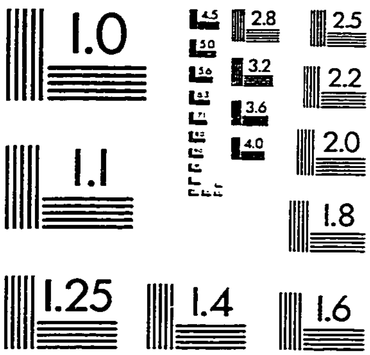
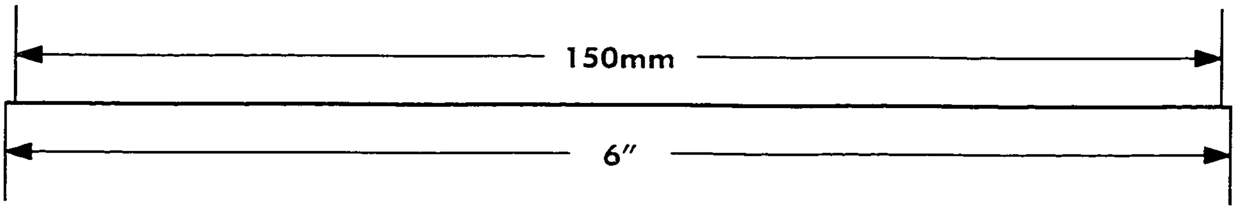
BE in Mechanical Engineering in January 95

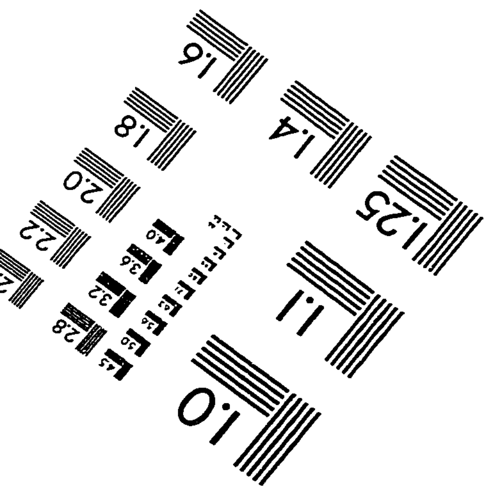
IMAGE EVALUATION TEST TARGET (QA-3)

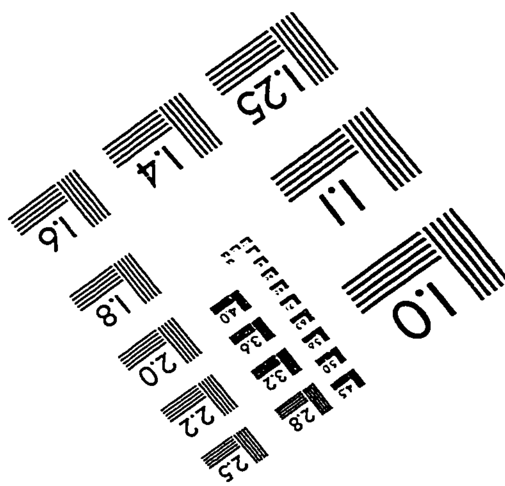












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